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Seabird Bycatch in U.S. West Coast Fisheries, 2002–18

March 2021

U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northwest Fisheries Science Center

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Seabird Bycatch in U.S. West Coast Fisheries, 2002–18

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U.S. DEPARTMENT OF COMMERCE

National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Northwest Fisheries Science Center

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Seabird Conservation Status

Number Killed 2002-2018

Species	Hook & Line	Trawl	Pot
Short-tailed Albatross	🐦		
Pink-footed Shearwater	🐦🐦	🐦🐦	
Leach's Storm-Petrel		🐦🐦	
Black-footed Albatross	🐦🐦🐦🐦	🐦🐦	🐦
Sooty Shearwater	🐦🐦🐦	🐦🐦🐦	
Laysan Albatross	🐦	🐦	
Cassin's Auklet		🐦🐦	
Western Gull	🐦🐦🐦	🐦🐦	
Northern Fulmar	🐦🐦	🐦🐦🐦	🐦
Arctic Herring Gull	🐦🐦	🐦	
Brown Pelican	🐦🐦🐦		
Glaucous-winged Gull	🐦🐦		
Common Murre	🐦🐦🐦	🐦🐦🐦	
Brandts Cormorant	🐦🐦	🐦🐦🐦	🐦🐦🐦
California Gull	🐦	🐦	
Double-crested Cormorant	🐦🐦		🐦🐦
Common Loon	🐦🐦		
Mew Gull	🐦		
Red-necked Phalarope	🐦		
Ring-billed Gull	🐦		
Green-winged Teal		🐦	
White-winged Scoter		🐦	
Shearwater Unidentified	🐦🐦🐦	🐦🐦🐦	
Gull Unidentified	🐦🐦🐦	🐦🐦🐦	🐦
Bird Unidentified	🐦🐦	🐦🐦	
Cormorant Unidentified	🐦🐦	🐦🐦🐦	🐦🐦🐦
Alcid Unidentified	🐦🐦	🐦	
Tubenoses Unidentified		🐦	
Storm-Petrel Unidentified		🐦	🐦
Murre Unidentified		🐦	

Number of birds	
🐦	1-10
🐦🐦	11-100
🐦🐦🐦	101-1000
🐦🐦🐦🐦	1000+

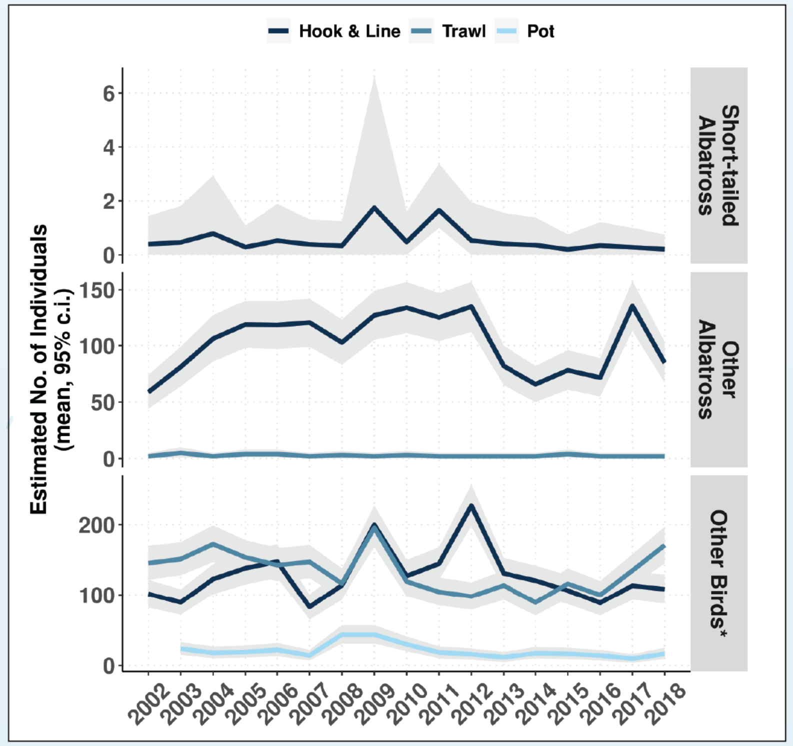
Conservation status

- Endangered
- Vulnerable
- Near threatened
- Least concern
- Unknown

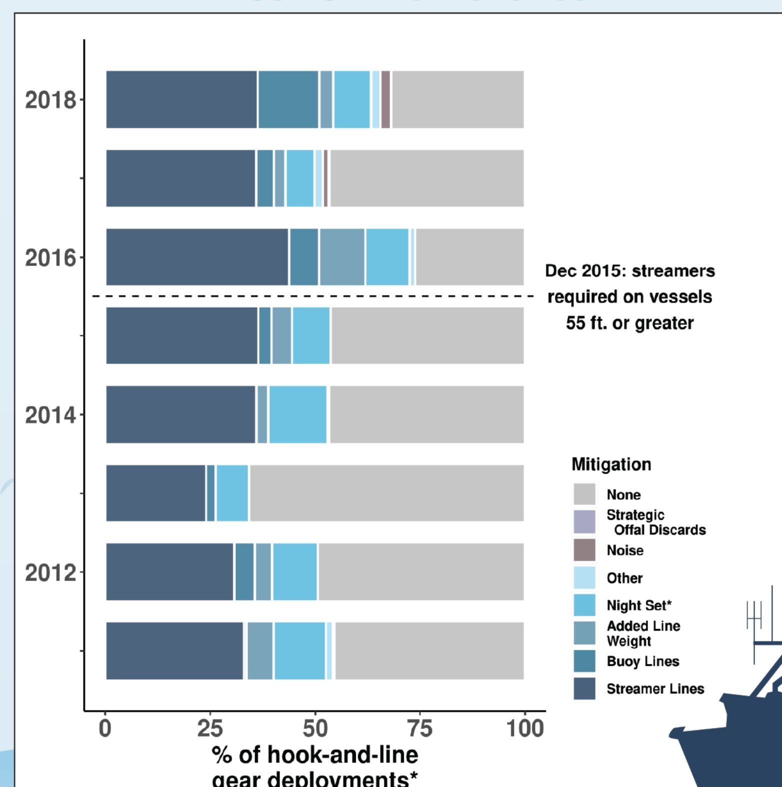
*Endangered under US ESA; all other categories are IUCN

ESA = Endangered Species Act
IUCN = International Union for the Conservation of Nature

Temporal Trends

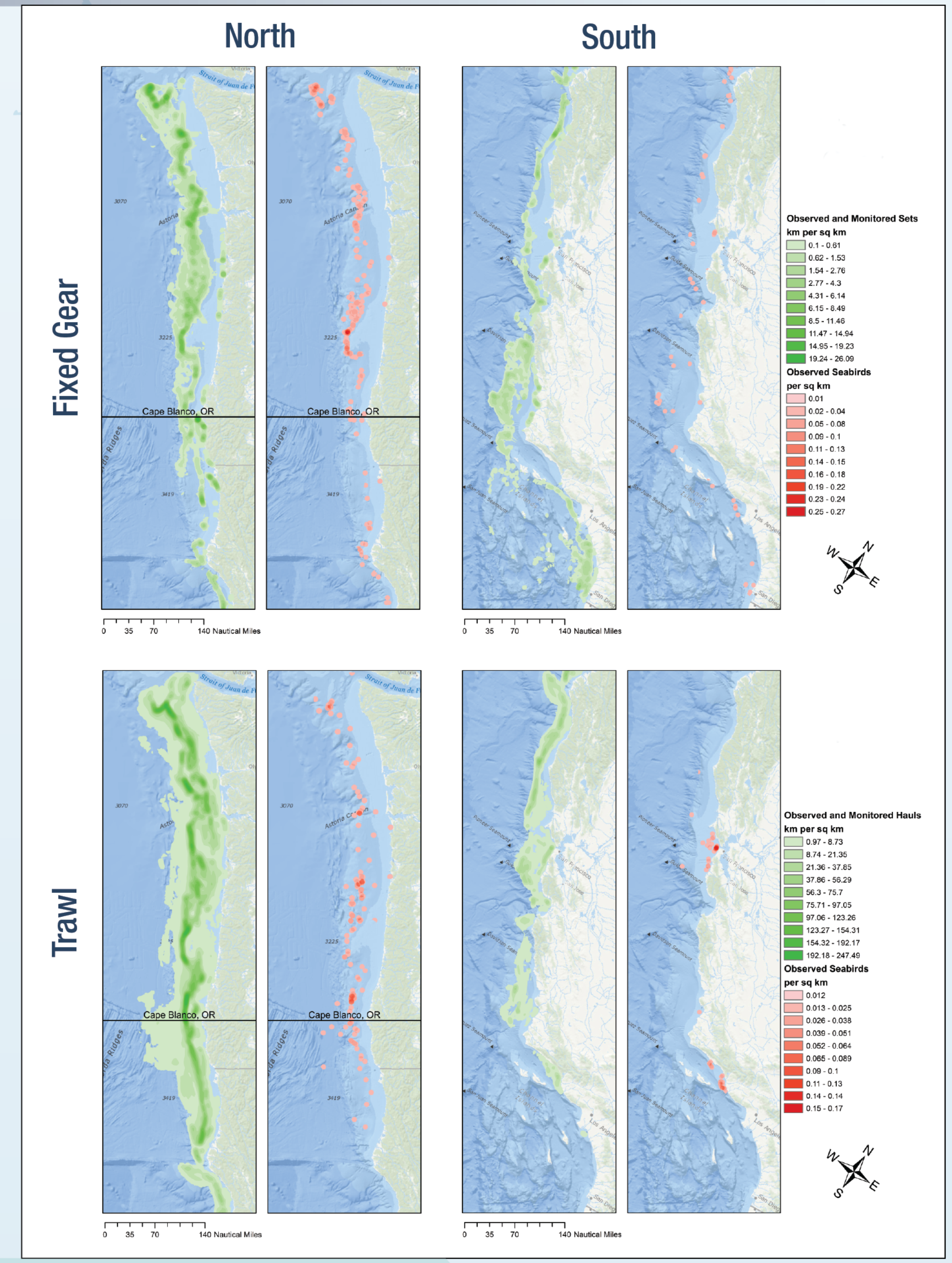


Mitigation Strategies in Hook & Line Fisheries



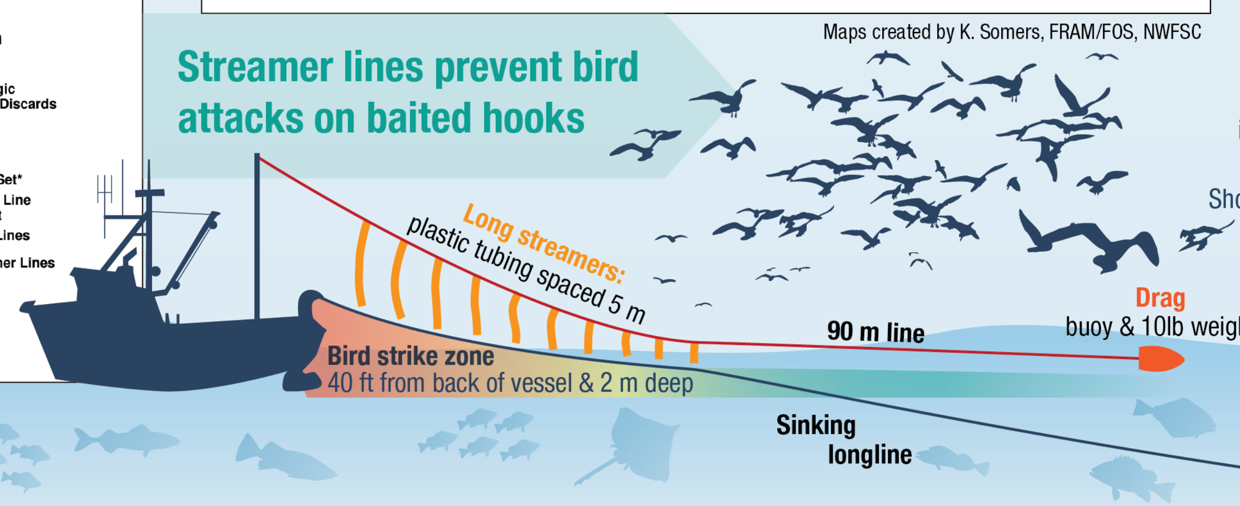
*Includes vessels using hook & line gears in the Sablefish, Daily Trip Limits, and Open Access Fixed Gear fisheries.

Spatial Distribution



Maps created by K. Somers, FRAM/FOS, NWFSC

Streamer lines prevent bird attacks on baited hooks



Management & Policy

JAN 2020
PFMC and NOAA regulation requires streamer lines or night-setting on non-tribal longline vessels 26 ft or longer (84 FR 67674).

NOV 2018
PFMC discussed streamer line use on longline vessels 26 to 55 ft in length.

MAY 2017
USFWS issues second Biological Opinion regarding Short-tailed Albatross in US West Coast Groundfish Fisheries.

DEC 2015
PFMC and NOAA regulation requires streamer lines on non-tribal longline vessels 55 ft or longer (80 FR 71975).

JUN 2013
PFMC convenes Groundfish Endangered Species Work Group.

NOV 2012
U.S. Fish & Wildlife issues first Biological Opinion regarding Short-tailed Albatross in US West Coast Groundfish Fisheries.

APR 2011
ESA-listed Short-tailed Albatross take on a hook-and-line vessel in the Sablefish fishery.

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Executive Summary

The California Current marine ecosystem on the U.S. West Coast (Washington, Oregon, and California) supports a diversity of marine organisms, including seabirds. This report summarizes interactions between U.S. West Coast fisheries and seabirds, and presents estimates of fleetwide seabird bycatch—based on data from fisheries and federal observer programs—for the years 2002–18.

Lethal and nonlethal interactions, as well as sightings, are presented for six fisheries using hook-and-line gear, eight fisheries using trawl gear, and five fisheries using pot gear. In 2017, three new fisheries were added for observation by the Northwest Fisheries Science Center (NWFSC): the Pacific halibut hook-and-line fishery, the California ridgeback prawn trawl fishery, and the California sea cucumber trawl fishery. The Pacific halibut fishery had relatively high black-footed albatross bycatch, and the California ridgeback prawn fishery had relatively high bycatch of Brandt's cormorant, compared to other fisheries. No birds were observed as bycatch in the California sea cucumber fishery. Recreational and tribal fisheries are not covered in this report.

A total of 47 bird species interacted with or were sighted in these fisheries over the 2002–18 period, up from 41 in the last report (Jannot et al. 2018). Thirteen species are considered endangered, threatened, vulnerable, or near-threatened by the U.S. Endangered Species Act (ESA) or the International Union for Conservation of Nature. The remaining 34 species are not listed, or are categorized as "least concern" (i.e., not at risk).

All three North Pacific albatross species interact with these fisheries: black-footed, Laysan, and the ESA-listed short-tailed albatross. To date, only one short-tailed albatross has been observed taken by these fisheries, and the mean estimated mortality for most years is less than one individual per year (Figure 1). However, black-footed albatross are caught annually in a number of fisheries reported here, primarily hook-and-line fisheries. Laysan albatross have occasionally been taken by fisheries reported here, but the mortalities are few and infrequent. The estimated mean mortalities of black-footed plus Laysan albatross ranged from a low of 60.77

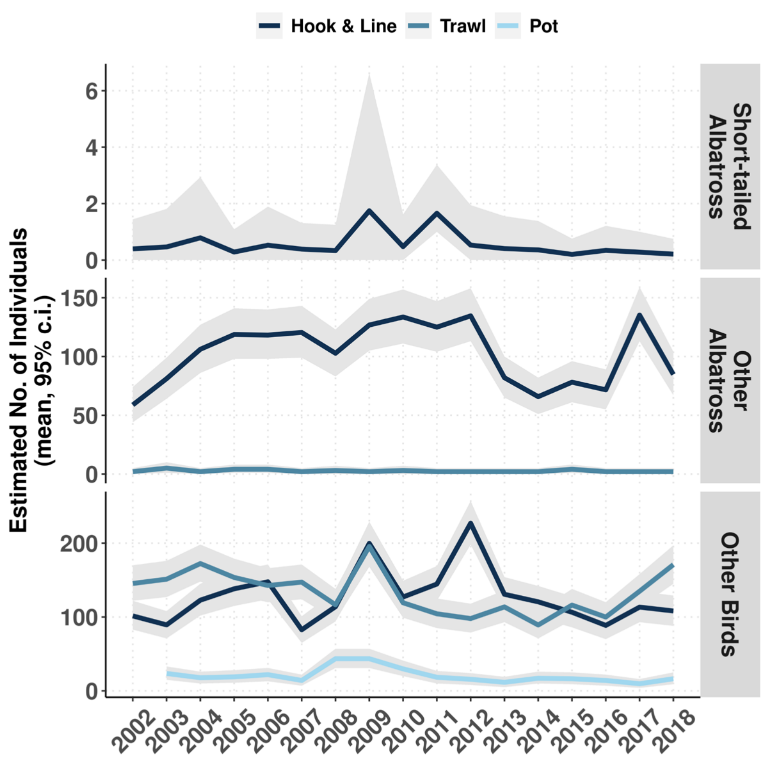

Figure 1. Estimated short-tailed albatross, other albatross, and other birds mortality (mean number of individuals, 2002–18).

individuals in 2002 to a high of 139.58 individuals in 2010 (see *Other albatross* in Figure 1). The 2018 estimate, across fisheries, for black-footed and Laysan albatross was 88.69 individuals (Figure 1). Other birds (i.e., nonalbatross) showed a peak in mortality during 2009 of 439.76 birds taken, and the 2018 mean estimated mortality of other birds was 296.48 (Figure 1).

Hook-and-line fisheries account for the largest number of albatrosses taken among the three gear categories (hook-and-line, trawl, pot). Over the last six years, hook-and-line fisheries accounted for 50–63% of seabird mortality, followed by trawl fisheries at 31–45%, and pot fisheries at 2–6% of bycatch (Table 1.) The largest number of albatross taken comes from limited entry (LE) sablefish vessels fishing hook-and-line gears. This prompted regulations requiring streamer lines on hook-and-line vessels fishing in U.S. West Coast groundfish fisheries; these were implemented in December 2015 for vessels 55 ft or longer. Beginning in January 2020, all vessels 26 ft or longer fishing with hook-and-line gear north of lat 36°N must use streamer lines during daylight hours (1 hr before sunrise to 1 hr after sunset). Alternatively, night-setting (1 hr after sunset to 1 hr before sunrise) can be used to reduce seabird bycatch on hook-and-line vessels in lieu of streamer lines.

Table 1. Estimated seabird mortality (numbers of individuals) and the percent of total mortality in U.S. West Coast fisheries, by gear type and year, 2012–18.

Sector	**Gear**	**2018**	**2017**	**2016**	**2015**	**2014**	**2013**
Limited entry sablefish	Hook-and-line	83.64	91.18	75.28	90.00	63.27	79.01
LE fixed gear DTL	Hook-and-line	52.52	52.21	48.96	52.25	78.15	88.00
Nearshore	Hook-and-line	26.70	30.73	26.12	31.53	31.79	32.13
PHLB derby	Hook-and-line	15.24	58.68	—	—	—	—
OA fixed gear	Hook-and-line	13.75	15.09	11.24	11.00	8.75	13.95
Catch share	Hook-and-line	1.24	1.00	—	—	4.76	—
Ridgeback prawn	Trawl	61.42	35.06	—	—	—	—
Catcher–processor	Trawl	53.00	53.01	64.01	64.00	49.00	113.00
OA CA halibut	Trawl	34.01	28.41	16.56	13.63	8.60	23.11
Pink shrimp	Trawl	26.45	22.39	25.34	46.49	32.54	34.47
MS catcher vessels	Trawl	0.00	0.00	1.00	2.00	2.00	0.00
Catch share	Trawl	—	1.00	4.00	2.00	1.02	4.09
Midwater hake EM	Trawl	—	1.00	—	—	—	—
Nearshore	Pot	16.41	9.65	14.08	16.39	17.10	10.59
Catch share EM	Pot	1.00	—	—	—	—	—
Limited entry sablefish	Pot	—	—	—	—	1.00	—
Catch share	Pot	—	—	—	—	—	1.00
Totals	Hook-and-line	193.09	248.89	161.60	184.78	186.72	213.09
	Trawl	174.88	140.87	110.91	128.12	93.16	174.67
	Pot	17.41	9.65	14.08	16.39	18.10	11.59
Percentages	Hook-and-line	50%	62%	56%	56%	63%	53%
	Trawl	45%	35%	39%	39%	31%	44%
	Pot	5%	2%	5%	5%	6%	3%

Bycatch of nonalbatross species is generally split evenly between hook-and-line and trawl gears. Seabird mortality is likely underestimated on trawl vessels, because seabirds can be killed or injured by striking cables that exit aft of the vessel during trawling. These cables are not routinely monitored in these fisheries. Significant levels of bycatch, especially of albatross, have been recorded in similar trawl fisheries around the globe (Favero et al. 2011, Maree et al. 2014, Tamini et al. 2015). In this report, we provide estimates of seabird mortality by cable strikes in the at-sea hake catcher–processor fleet. Pot gears appear to catch very few seabirds.

In earlier versions of this report (Jannot et al. 2011), we used ratios to estimate seabird bycatch. In the previous report (Jannot et al. 2018), we implemented an improved method for bycatch estimation. We applied Bayesian models to estimate total bycatch and associated error for fisheries with less than 100% observer monitoring. These methods have been used with other rare bycatch species, including cetaceans, delphinids, pinnipeds, sea turtles, and sharks (Jannot et al. 2011). The Bayesian method better estimates uncertainty and provides fleetwide estimates even in years when no seabird mortality was recorded by fisheries observers.

In the previous report (Jannot et al. 2018), we assumed the estimated bycatch rate, θ, was constant through time. In this report, we explicitly test for constant bycatch rate. We also compare models using alternative measures of fishing effort (number of gear deployments, number of gear units, amount of landed catch) and alternative distributions of the bycatch process (Poisson versus negative binomial). The results presented here represent the optimal model when comparing these parameters.

Acknowledgments

The authors gratefully acknowledge the hard work and dedication of observers and staff from the Northwest Fisheries Science Center's Fisheries Observation Science Program (FOS). We thank Su Kim of the NWFSC Communications Program for producing the infographic in this report. We thank Eric Ward (NWFSC) for developing the R package `bycatch`, which is used for the Bayesian models and MCMC simulations. This report benefited from the comments and suggestions of Craig Russell (NWFSC). We thank Al Brown (IBSS Corporation) for technical editing. We thank our partners at the Pacific States Marine Fisheries Commission who provide us with data from the IFQ electronic monitoring EFP and landings data from PacFIN. Funding for Anna Wuest was generously provided by the 2019 Ernest F. Hollings Undergraduate Scholarship Program (NOAA).

A note about tables:

Tables 1–22, as well as Tables A-1–A-3 in Appendix A and Table B-1 in Appendix B, have been typeset and included in this report. These tables are also available, together with all the other mentioned tables, by downloading the Excel files from the report's NOAA Institutional Repository[1] record by clicking on the *Supporting Files* tab. Note also that the following tables have been typeset on legal-sized paper to accomodate large amounts of data: Tables 4–10, 12, and 15–19. Printing them on letter-sized paper may result in reduced legibility.

[1] https://repository.library.noaa.gov/

Introduction

The California Current marine ecosystem on the U.S. West Coast (Washington, Oregon, and California) supports a diversity of marine organisms, including seabirds. Managing and conserving marine biodiversity requires accounting for human-induced mortality to seabirds. Seabirds overlap with commercial fisheries operating within the U.S. Exclusive Economic Zone (EEZ) on the U.S. West Coast, which can cause incidental human-induced mortality, or bycatch, of these species. This report summarizes interactions between U.S. West Coast fisheries and seabirds, and presents estimates of fleetwide bycatch for seabirds based on fishery and federal observer program data for the years 2002–18.

More species of seabirds are threatened or endangered than any other bird group, and seabird populations have declined faster than other bird groups (Croxall et al. 2012, Lascelles et al. 2016). Seabird bycatch is considered a major threat to seabird populations, and, on a relative scale, is a threat to seabirds second only to invasive species (Croxall et al. 2012). Furthermore, bycatch affects a larger proportion of seabird populations than most other human threats to these species. Fishing vessels using longline gear kill 160–320,000 seabirds globally each year (Anderson et al. 2011). Although global estimates are lacking for trawl fisheries, individual studies indicate that global seabird mortality from trawl gear is likely to be of a similar scale (Bartle 1991, Weimerskirch et al. 2000, González-Zevallos et al. 2007, Watkins et al. 2008, Tamini et al. 2015). Quantifying the lethal and sublethal effects of fisheries on seabirds is the first step toward understanding the impact of fisheries on seabird populations and developing solutions to minimize seabird bycatch.

Species-specific characteristics such as feeding locations and times, diet preferences, sizes, and individual physical conditions play a role in the susceptibility of seabirds to fishing mortality. Albatross populations are especially vulnerable to the impact of bycatch mortality because they exhibit delayed maturity, low annual fecundity, and long life spans—life history characteristics that make populations vulnerable to decline from even small increases in mortality. Commercial fisheries have been implicated in the decline of many albatross and petrel species (Weimerskirch et al. 1997, Lewison and Crowder 2003, Baker et al. 2007). Fifteen of 22 albatross species (family Diomedeidae) are threatened with extinction, one of the highest proportions for any bird family (Butchart et al. 2004, Croxall et al. 2012, IUCN 2020).

The U.S. Fish and Wildlife Service (USFWS) manages seabird populations in the United States by enforcing laws and regulations pertaining to seabirds and other migratory birds. NOAA's Northwest Fisheries Science Center (NWFSC) and West Coast Region (WCR), in collaboration with USFWS, gather data on fishery-related mortality of seabirds in U.S. West Coast fisheries to aid USFWS and other agencies in their efforts to quantify and mitigate seabird bycatch. Albatross are one of the most threatened groups of seabirds and the most frequently caught group along the U.S. West Coast. We highlight albatross mortality in this report.

Seabirds in the California Current

The U.S. West Coast supports a diversity of seabirds of both national and international importance; these species exhibit a wide range of life history characteristics. Seabirds interacting with coastal fisheries include species that breed locally. For example, U.S. West Coast populations of nesting Brandt's cormorants (*Phalacrocorax penicillatus*) and western gulls (*Larus occidentalis*) represent the majority of the global populations of these species (USFWS 2005). In addition to resident species, the California Current ecosystem hosts millions of seabird migrants, including three species of global conservation concern: the short-tailed albatross (*Phoebastria albatrus*), listed as endangered under the U.S. Endangered Species Act (ESA), and the black-footed (*P. nigripes*) and Laysan (*P. immutabilis*) albatrosses, listed as near-threatened on the International Union for Conservation of Nature (IUCN) Red List. Other coastal seabirds that are ESA-listed include California least terns (*Sternula antillarum browni*, endangered) and the marbled murrelet (*Brachyramphus marmoratus*, threatened; Table 2). All three of these species interact or have the potential to interact with commercial fishing vessels in this region. In addition to the albatross and ESA-listed species already mentioned, eight others categorized by the IUCN as vulnerable or near-threatened also interact with U.S. West Coast fisheries (Table 2).

All seabirds in the California Current ecosystem are highly mobile and require an abundant food source to support their high metabolic rates (Ainley et al. 2005). Thus, oceanic productivity and prey availability drive seabird abundance along the U.S. West Coast (Tyler et al. 1993, Ainley et al. 2005). Coastal upwelling, which delivers nutrient-rich water to the surface, determines the seasonal and latitudinal distribution of prey biomass, which seabirds follow (Tyler et al. 1993). On the U.S. West Coast, upwelling is most intense south of lat 42°50′N (Cape Blanco, Oregon; Bakun et al. 1974, Barth et al. 2000), which appears to support a large percentage of the nesting sites of locally breeding seabirds (Tyler et al. 1993). The location of stable nesting sites reflects oceanographic conditions that support long-term food availability (Tyler et al. 1993, Naughton et al. 2007). Transient species to the California Current system are also most abundant in areas of strong upwelling intensity and high productivity (Briggs and Chu 1986, Hyrenbach et al. 2002).

The U.S. West Coast upwelling not only varies by latitude, but also by season, thereby influencing both the latitudinal and seasonal distribution of seabirds. The U.S. West Coast has three distinct oceanic seasons: Upwelling, Oceanic, and Davidson Current (Ford et al. 2004). The Upwelling season coincides with late spring and summer, when northerly winds transport surface waters southward and away from the coast. The distribution of breeding species in summer largely reflects the location of nesting colonies, which are most prevalent adjacent to the central and northern portions of the California Current system (Tyler et al. 1993, Ford et al. 2004). However, during this time, productivity and prey abundance associated with upwelling bring so many visiting species to the coast that they outnumber the breeding species. Commonly observed visiting species in summer include the sooty shearwater (*Puffinus griseus*), northern fulmar (*Fulmarus glacialis*), and black-footed albatross (Tyler et al. 1993). During the fall Oceanic season, northerly winds and upwelling intensity decrease, and sea surface temperature reaches its annual maximum. Several species that nest farther south in Mexico and southern California move northward, including the brown pelican

(*Pelecanus occidentalis*) and storm-petrels (Hydrobatidae). As winter approaches, southern nesters return south and breeders from boreal nesting colonies become more abundant, particularly along the California coast (Tyler et al. 1993). In winter, warmer water delivered by the Davidson Current reduces primary production along the U.S. West Coast. Seabird abundance during this Davidson Current season is generally low (Tyler et al. 1993).

Table 2. U.S. ESA status, IUCN status, number of observed mortalities (takes), number of nonlethal interactions, and number of sightings for all birds recorded by observers on U.S. West Coast fishing vessels observed by FOS, 2002–18. Estimated fishing mortality by year for each species is given in Table 3.

	Conservation status		Observed		
Common name	**ESA**	**IUCN**	**Takes**	**Interactions**	**Sightings**
Short-tailed albatross	Endangered	Vulnerable	1	69	176
California least tern	Endangered	Not assessed	0	0	5
Marbled murrelet	Threatened	Endangered	0	1	11
Ashy storm-petrel	Not listed	Endangered	0	1	0
Pink-footed shearwater	Not listed	Vulnerable	5	5	48
Leach's storm-petrel	Not listed	Vulnerable	29	13	30
Black-legged kittiwake	Not listed	Vulnerable	0	0	1
Sooty shearwater	Not listed	Near threatened	58	26	7,858
Snowy plover	Not listed	Near threatened	0	1	0
Heermanns gull	Not listed	Near threatened	0	3	34
Laysan albatross	Not listed	Near threatened	3	55	87
Black-footed albatross	Not listed	Near threatened	383	2,933	4,534
Cassin's auklet	Not listed	Near threatened	11	37	3
Green-winged teal	Not listed	Not assessed	10	0	0
Short-tailed shearwater	Not listed	Least concern	0	1	0
Wilsons warbler	Not listed	Least concern	0	1	0
South polar skua	Not listed	Least concern	0	1	0
Pigeon guillemot	Not listed	Least concern	0	0	99
Rhinoceros auklet	Not listed	Least concern	0	2	2
Semipalmated plover	Not listed	Least concern	0	1	0
Tufted puffin	Not listed	Least concern	0	1	17
Northern fulmar	Not listed	Least concern	269	2,559	193
Common loon	Not listed	Least concern	1	1	0
Pacific loon	Not listed	Least concern	0	0	2
Fork-tailed storm-petrel	Not listed	Least concern	0	101	6
California gull	Not listed	Least concern	2	1	32
Mew gull	Not listed	Least concern	1	0	0
Ring-billed gull	Not listed	Least concern	1	0	0
Glaucous-winged gull	Not listed	Least concern	4	4	7
Western gull	Not listed	Least concern	72	7,681	157
Arctic herring gull	Not listed	Least concern	13	0	1
Orange-crowned warbler	Not listed	Least concern	0	3	0
White-winged scoter	Not listed	Least concern	3	0	0
Fox sparrow	Not listed	Least concern	0	1	0
American white pelican	Not listed	Least concern	0	0	0

Table 2 (continued). U.S. ESA status, IUCN status, number of observed mortalities (takes), number of nonlethal interactions, and number of sightings for all birds recorded by observers on U.S. West Coast fishing vessels observed by FOS, 2002–18.

	Conservation status		Observed		
Common name	**ESA**	**IUCN**	**Takes**	**Interactions**	**Sightings**
Brown pelican	Not listed	Least concern	6	11	101
Red-billed tropicbird	Not listed	Least concern	0	0	1
Double-crested cormorant	Not listed	Least concern	2	2	0
Pelagic cormorant	Not listed	Least concern	0	0	7
Brandts cormorant	Not listed	Least concern	28	5	0
Red-necked phalarope	Not listed	Least concern	1	1	0
Lesser goldfinch	Not listed	Least concern	0	1	0
Long-tailed jaeger	Not listed	Least concern	0	1	0
Pomarine jaeger	Not listed	Least concern	0	1	1
Brown booby	Not listed	Least concern	0	5	2
Ancient murrelet	Not listed	Least concern	0	0	1
Common murre	Not listed	Least concern	70	8	96

Seabird Management

NOAA's National Marine Fisheries Service (NMFS, or NOAA Fisheries) is responsible for managing marine ecosystems, including accounting for all fisheries bycatch—which includes seabirds. NOAA Fisheries works closely with the primary agency responsible for seabird management, the U.S. Fish and Wildlife Service (USFWS), to assist in seabird management.

Currently, there are multiple U.S. laws, U.S. regulations, and NOAA policies that govern seabird bycatch in commercial fisheries, including:

- The Migratory Bird Treaty Act (MBTA) of 1918.
- The Endangered Species Act (ESA) of 1973.
- The U.S. National Plan of Action for Reducing the Incidental Catch of Seabirds in Longline Fisheries (NPOA-Seabirds).
- Executive Order 13186, "Responsibilities of Federal Agencies to Protect Migratory Birds."
- NOAA Fisheries' National Bycatch Reduction Strategy.
- The Magnuson–Stevens Fishery Conservation and Management Act (MSA) of 1976.
- The National Environmental Policy Act (NEPA) of 1970.
- The Fish and Wildlife Coordination Act (FWCA) of 1934.
- The National Marine Sanctuaries Act (NMSA) of 1972.
- USFWS's list of Birds of Conservation Concern (USFWS 2008).

The MBTA, passed in 1918, affirms and implements the United States' commitment to four international conventions with Canada, Japan, Mexico, and Russia for the protection of a shared migratory bird resource. The MBTA protects all migratory birds and their parts (including eggs, nests, and feathers). Migratory birds live, reproduce, or migrate across international borders at some point during their annual life cycle. In total, 836 bird species are protected under the MBTA. The MBTA applies to the area in U.S. coastal waters extending 4.8 km from shore, and violations carry criminal penalties.

The purpose of the ESA (1973) is to protect and recover imperiled species and the ecosystems upon which they depend. Currently, there are over 1,400 species in the United States listed as threatened or endangered under the ESA. The ESA offers seabirds additional protective measures beyond the MBTA. The ESA authorizes protective measures for listed species, which include restrictions on taking, transporting, or selling specimens. USFWS has jurisdiction over all endangered birds in the United States, including the short-tailed albatross, which is found along the U.S. West Coast and overlaps and interacts with U.S. West Coast fisheries.

U.S. West Coast Fisheries Management

Fishery Descriptions

The U.S. West Coast fisheries that catch groundfish are multispecies fisheries that utilize a variety of gear types (Appendix A, Tables A-1–A-3). These fisheries harvest species designated in the Pacific Coast Groundfish Fishery Management Plan (FMP; PFMC 2019) or incidentally catch FMP groundfish in pursuit of nongroundfish target species. These fisheries are managed by the Pacific Fishery Management Council (PFMC) in collaboration with the states of Washington, Oregon, California, and Idaho, and other stakeholders. Over 90 species are listed in the groundfish FMP, including a variety of rockfish, flatfish, roundfish, skates, and sharks. These species are found in both federal (>4.8 km offshore to the EEZ) and state waters (0–4.8 km). Groundfish are both targeted and caught incidentally by trawl nets, hook-and-line gears, and fish pots.

Under the FMP, the groundfish fishery consists of four management components:

- The limited entry (LE) component encompasses all commercial fishers who hold a federal limited entry permit. The total number of LE permits available is restricted. Vessels with an LE permit are allocated a larger portion of the total allowable catch for commercially desirable species than vessels without an LE permit.
- The open access (OA) component encompasses commercial fishers who do not hold a federal LE permit. Some states require fishers to carry a state-issued permit for certain OA fisheries.
- The recreational component includes recreational anglers who target or incidentally catch groundfish species. Estimates of seabird bycatch in recreational fisheries are not covered by this report.
- The tribal component includes native tribal commercial fishers in Washington state who have treaty rights to fish groundfish. Estimates of seabird bycatch from tribal fisheries are not included in this report.

The LE and OA components can be further subdivided into fishery sectors based on gear type, target species, permits, and other regulatory factors (Tables A-1–A-3).

In 2011, the LE bottom trawl fishery of the U.S. West Coast groundfish fishery began fishing under an individual fishing quota (IFQ) management program. An IFQ is defined as a federal permit under a limited access system to harvest a quantity of fish, representing a portion of the total allowable catch of a fishery, that can be received or held for exclusive use by a person (Magnuson–Stevens Act of 1976). The implementation of the IFQ management program in 2011 resulted in a mandate that vessels must carry NMFS observers or electronic monitoring (EM) equipment on all IFQ fishing trips. Prior to the IFQ program, vessels in this fishery could only fish with bottom trawl gear. Since the IFQ implementation, bottom and midwater trawl, hook-and-line, and pot gears are all allowed to be fished under this permit.

NWFSC Fisheries Observation Science Program

The Fisheries Observation Science Program (FOS) at NWFSC places at-sea observers on commercial fisheries that catch groundfish as target species or bycatch in the U.S. West Coast EEZ. At-sea observer data inform independent estimates of the amount and types of species caught and discarded in these fisheries. The observer program has two units: the At-Sea Hake Observer Program (A-SHOP) and the West Coast Groundfish Observer Program (WCGOP). Each observes distinct sectors of the groundfish fishery (Tables A-1–A-3).

At-Sea Hake Observer Program (A-SHOP)

A-SHOP observes the fishery that catches and delivers Pacific hake (*Merluccius productus*, a.k.a. Pacific whiting, henceforth referred to as hake) at sea, including nontribal catcher–processors and catcher vessels delivering to motherships (Table A-1). A-SHOP has conducted observations of the U.S. West Coast at-sea hake fishery since 2001. Prior to 2001, observer coverage of the U.S. West Coast at-sea hake fishery was conducted by the North Pacific Groundfish Observer Program. Information on A-SHOP and the data collection methods used can be found in the A-SHOP observer manual (NWFSC 2020a). The at-sea hake fishery has mandatory observer coverage, with each vessel over 38 meters carrying two observers. Beginning in 2011, under IFQ/Co-op Program management, all catcher vessels that deliver catch to motherships are required to carry observers or use EM equipment.

Observers on at-sea hake vessels take a random sample of the total catch, including both the component to be retained and that to be discarded. With one or two observers on board each vessel, nearly 100% of tows are sampled. However, because of the large volume of catch from each tow, it is typically only possible to sample 30–60% of the total tow catch. When a sample is collected, the species within it are identified, counted, and weighed. The resulting data are expanded to the tow level and used to summarize catch by species in the fleet as a whole.

West Coast Groundfish Observer Program (WCGOP)

The WCGOP program was established in May 2001 by NOAA Fisheries in accordance with the Pacific Coast Groundfish Fishery Management Plan (USOFR 2001). This regulation requires all vessels that catch groundfish in the U.S. EEZ from 4.8–322 km offshore to carry an observer when notified to do so by NMFS or its designated agent. Subsequent state rule-making has extended NMFS's ability to require some vessels fishing in the 0–4.8-km state territorial zone to carry observers.

WCGOP observes multiple federal groundfish fisheries, including IFQ shoreside delivery of groundfish and hake, LE and OA fixed gear fisheries, and the fishery that targets Pacific halibut (Tables A-1 and A-2). WCGOP also observes several state-permitted fisheries that target or incidentally catch groundfish, including the Washington, Oregon, and California pink shrimp trawl, the Oregon and California nearshore fixed gear, California halibut trawl, California ridgeback prawn, and the California sea cucumber fisheries (Table A-3).

Shoreside IFQ vessels are required to carry an observer on 100% of fishing trips. In 2015, some vessels obtained an exempted fishing permit (EFP) which allowed them to carry EM equipment for catch monitoring in lieu of a human observer. These IFQ EM vessels have 100% monitoring of catch of quota species; scientific observers are placed on about 30% of IFQ EM vessels to provide estimates of nonquota species catch. In non-IFQ fishery sectors, there is no mandate for 100% coverage, and the amount of observer coverage varies among and within sectors among years (Somers et al. 2019b). In these sectors, permits are selected for observation by WCGOP using a random sampling design without replacement. First, WCGOP determines the amount of time (based on available resources) it will take to observe the entire fleet; this is termed the selection cycle. Next, WCGOP aggregates locations along the U.S. West Coast into port groups. The permits or vessels in each fishery sector are assigned to a port group based on the location of their previous year's landings. Within each port group, the permits or vessels are randomly selected for coverage. Permits in most fisheries[1] are selected for one- or two-month periods which coincide with cumulative trip limit periods used in management. LE fixed gear sablefish endorsed (primary) permits are selected for the entire sablefish season (1 April through 31 October) until their quota is caught. The Pacific halibut fishery is selected for the entire season, which consists of anywhere from one to three 24-hour openers per year. This selection process is designed to produce a logistically feasible sampling plan with a distribution of observations throughout the entire geographic and temporal range of each fishery. Once a permit or vessel has been selected for coverage, WCGOP attempts to observe all trips and sets that the vessel makes during the coverage period.

The annual percentage of observer coverage in nonhake fisheries ranges from <1% to over 30% (Somers et al. 2019b), as defined by the proportion of targeted fishery landings that are observed. Coverage varies among fisheries based on priority. Higher-priority fisheries receive the highest observer coverage. A list of fisheries in order of coverage priority can be found in the WCGOP manual (NWFSC 2020b).

Fisheries observers monitor and record catch data on commercial fishing vessels by following protocols in the WCGOP manual (NWFSC 2020b). Observer sampling focuses on discarded catch, and supplements existing fish ticket landing receipt data to inform weights of retained catch. Observers generally sample 100% of tows/sets made during a trip. On trawlers, the total weight of discarded catch is estimated, and the discarded catch is then sampled for species composition. The species composition sample could represent either a complete census or a subsample of all discarded catch. On fixed gear (hook-and-line and pot gears) vessels, observers sample from 50 to 100% of the catch from each set (similar to at-sea hake observer sampling methodology).

[1] This group comprises the LE bottom trawl fishery prior to the IFQ program (2002–10), the LE sablefish fixed gear nonendorsed (nonprimary) fishery, the OA fixed gear fishery, the Oregon and California nearshore fisheries, the California halibut fishery, state-managed pink shrimp fisheries, and the California ridgeback prawn and California sea cucumber fisheries.

Seabird Mortality

Observer Sampling for Seabirds

All observers receive training on seabird data collection and identification, including the three ESA-listed species: short-tailed albatross, California least tern, and marbled murrelet. A-SHOP and WCGOP place sampling seabird bycatch as the highest priority of observer duties. Observers sample and document seabirds when any of the following occur:

1. Fishing gear catches any seabird, regardless of whether the individual lives or dies.
2. A seabird interacts with the fishing vessel but is not caught in the gear.
3. An ESA-listed seabird is sighted.

Observers identify each bird to species or the lowest possible taxonomic unit, and they count, weigh (if bird in hand), and photograph the bird(s). If the seabird has a tag or band, observers remove (from dead birds only) or document tag number(s) and/or band color(s) and note the banding pattern (which leg(s), order of colored bands, etc.). Bird band numbers, colors, and associated information are reported to NWFSC and USFWS staff. Observers must document all sightings of ESA-endangered or -threatened seabirds (Table 2). When time allows, sightings of other species are documented.

Observed Fishery Interactions

Observers record a variety of fishery interactions with seabirds. Both observer programs use a system of coded categories to document interactions (Table 3).

Table 3. Descriptors used by fishery observers to describe types of seabird interactions with U.S. West Coast fishing vessels.

Category	Description
Lethal Removal—Not Trailing Gear	Animals killed by vessel personnel to prevent serious damage to or loss of gear, catch, or human life. No gear attached to animals when returned to sea.
Lethal Removal—Trailing Gear	Animals killed by vessel personnel to prevent serious damage to or loss of gear, catch, or human life. Pieces of gear, including parts of net or line, attached to animals when returned to sea.
Killed by Gear	Animals killed by interaction with gear.
Vessel Strike	Animals struck by some part of the vessel, including hull, mast, rigging or cables.
Rig Strike	Animals made contact with vessel's rigging, excluding third wire, paravane, or warp cable interactions. (A-SHOP only.)
Third Wire, Paravane, or Warp Cable Contact	Animals made contact with third wire, paravane, or warp cables. (A-SHOP only.)

Table 3 (continued). Descriptors used by fishery observers to describe types of seabird interactions with U.S. West Coast fishing vessels.

Category	Description
Entangled in Gear—Not Trailing Gear	Animals entrapped or entangled in fishing gear, but escape or are released alive. Includes instances where an individual is hooked. No gear attached to animals when returned to sea.
Entangled in Gear—Trailing Gear	Animals entrapped or entangled in fishing gear, but escape or are released alive. Includes instances where an individual is hooked. Pieces of gear, including parts of net or line, attached to animals when returned to sea.
Feeding on Bait—Attached to Hook	Animals feeding on bait that is still attached to hooks.
Feeding on Bait—Floating Free	Animals feeding on bait that has come free of gear.
Feeding on Discarded Catch	Animals feeding on any part of discarded catch.
Feeding on Offal	Animals feeding on the discarded products of fish processing (e.g., fish guts).
Feeding on Catch	Animals feeding on fish prior to the fish being brought on vessel.
Foraging, Not Bait	Animals foraging or feeding near the vessel but not feeding on bait or discards. (A-SHOP only.)
Deterrence Used	Vessel personnel attempted to deter interaction with animals using: Firearm, Gaff, Acoustic Device, Yelling, or Other method.
Boarded Vessel	Animals boarded fishing vessel of own volition.
Unknown	Vessel or vessel personnel interacted with animals, but observer did not directly view interaction nor ascertain what interaction was. Observer notes describe interaction details, when possible.
Other	Animals involved in interactions with vessel; however, interaction type is not included in list of interaction codes. Observer notes describe interaction details, when possible.
Sighting Only	Animals did not interact with vessel, but animals were within observation distance of vessel and/or observer.

Interactions need to be screened for inclusion (or exclusion) from bycatch estimation, as not all interactions lead to mortality. To aid this process, in 2015, WCGOP instituted a protocol to record one of five possible outcomes of an interaction:

1. *Alive—no visible signs of injury*: Individual(s) alive and showing no visible signs of injury because of the interaction.
2. *Alive—visible signs of injury*: Individual(s) alive, but showing signs of injury that might be a result of the interaction.
3. *Dead or Unresponsive carcass*: Individual(s) dead or unresponsive.
4. *Not applicable*: Code used only for sightings.
5. *Unknown*: Observer is unsure of outcome. Observer notes describe interaction details, when possible.

A-SHOP observers began recording one of six possible interaction outcomes in 2010:

1. *Flew Off*: Individual flew off or left the immediate area of the interaction.
2. *Released Flew Off*: Any bird that was removed from the vessel or gear and flew off upon release.
3. *Released to Water*: Individual was removed from the vessel or gear and returned to the water.
4. *Died*.
5. *Carcass Salvaged*: Whole specimen of dead bird was recovered and preserved.
6. *Observer End Observing*: Observer stops recording the event because other duties take priority. Common outcome for sightings.

We defined any interaction that was immediately lethal or thought to lead to mortality, as a mortality, even if the animal was alive at the time of the observation. Using language adopted from the ESA, we refer to these lethal interactions as "takes." Section 3 of the ESA specifies the term "take" to mean "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct" (Endangered Species Act of 1973). The combination of the interaction category, interaction outcome, and specific details in observer notes recorded at the time of the interaction informed take designations. Observers typically detail the nature of the injury and changes in the animal's behavior following its release. Noted factors indicating a potential mortality include:birds with visible bleeding, broken bones, lost feathers, and birds that did not fly away or return to normal behavior within a few minutes of the interaction. Not all interactions resulted in a mortality and were thus judged to be nonlethal (i.e., not a take).

For ESA-listed seabirds, observers are instructed to collect and freeze the carcasses of any dead birds and transfer them to the USFWS. Regulations also require observers to care for any short-tailed albatross (STAL) brought on board injured until USFWS takes possession. The WCGOP (NWFSC 2020b) and A-SHOP (NWFSC 2020a) sampling manuals describe protocols for the collection of dead, and for the care of injured, ESA-listed seabirds.

Opportunistic takes

For takes to be used in bycatch estimation, they must either be obtained from a randomly sampled portion of the haul or a complete census of the haul. In some cases, observers witness seabird interactions that occur outside of sampled catch (e.g., informed of an interaction by the crew, bird struck vessel or rigging, etc.). Observers record these nonrandom, opportunistic observations of seabird takes whenever they occur. Opportunistic data are excluded from bycatch expansion because they are not randomly sampled. However, opportunistic samples are included in the final total mortality estimate, by simply adding the number of opportunistic takes to the expanded bycatch estimate. Table B-1 in Appendix B presents both the randomly sampled and opportunistically sampled seabird takes by year, fishery and gear type. Figure B-1 in Appendix B presents opportunistic samples as a proportion of all samples across all fisheries by year for albatross and other birds.

Seabird Bycatch

In this report, we applied a Bayesian modeling approach to estimate total bycatch and associated variability for fisheries with less than 100% observer monitoring, similar to Jannot et al. (2018). These methods have been used with other rare bycatch species, including cetaceans, delphinids, pinnipeds, sea turtles, and sharks (Martin et al. 2015). We modeled bycatch rate and inferred annual expected mortality given a specified level of effort. Fleetwide bycatch for fisheries with less than 100% observer coverage was estimated using observer coverage rate (observed landings ÷ total landings). All estimates reported in the tables are based on the Bayesian estimates (±95% confidence limits).

Even though ratio estimators have been widely used in discard estimation (Stratoudakis et al. 1999, Borges et al. 2005, Walmsley et al. 2007), including in the U.S. West Coast fisheries (e.g., Jannot et al. 2011), ratio estimators are known to make restrictive assumptions and can be biased, especially when bycatch events are rare (Rochet and Trenkel 2005, Carretta and Moore 2014, Martin et al. 2015). Ratio estimators rely heavily on the assumption that bycatch is proportional to some metric or proxy of fishing effort, such as fishery landings, an assumption not often supported by data (Rochet and Trenkel 2005). In some cases, bycatch might vary nonlinearly, or even be unrelated to the ratio estimator denominator. Most seabird species reported here are rarely caught. The rarity of seabird bycatch, combined with less than 100% observer monitoring in many of these fisheries, makes it difficult to assess the link between seabird bycatch and fishing effort. Low levels of observer coverage can produce biased estimates when ratio estimators are used to calculate fleetwide bycatch of protected species (Carretta and Moore 2014, Martin et al. 2015).

Because albatross are one of the most threatened groups of seabirds (Butchart et al. 2004, Croxall et al. 2012, IUCN 2020) and the most frequently caught group along the U.S. West Coast (Table 4, Figure 2), we present results for the three albatross species combined and compare those results with patterns of bycatch for nonalbatross birds combined.

Total Fishing Mortality

Total seabird mortality for all species across all fisheries is shown, by year, in Table 4. Estimates in Table 4 are the combined sum of the observed mortality of individuals from 100%-observed fisheries, the sum of the opportunistically sampled individuals, and the mortality estimated from randomly sampled individuals in fisheries with less than 100% observer coverage. The "exact" confidence intervals are given as "lower confidence limit (LCL) – upper confidence limit (UCL)" in the adjacent column of Table 4, and as a gray ribbon around the lines in Figure 2. Details of the confidence interval calculations can be found in Methods.

Black-footed albatross (BFAL) are the most frequently caught species (Table 4). From 2012 to 2018, black-footed albatross mortality went from a near high of 135 birds in 2012 to a low of 69 in 2014, increased to 138 in 2017, and dropped to 88 in 2018 (Table 4)—averaging 96 BFALs estimated per year from 2012–18. Bycatch estimates of Laysan and short-tailed albatross were much smaller than black-footed estimates, an average of less than one per year of each species from 2012–18. Pink-footed shearwaters, a species of conservation concern, show a consistent but low amount of annual fishing mortality ranging between five and nine birds per year for the 2012–18 period. Sooty and unidentified shearwaters, followed by gulls, northern fulmars, and common murres, make up the remainder of the most-common bird bycatch in these fisheries.

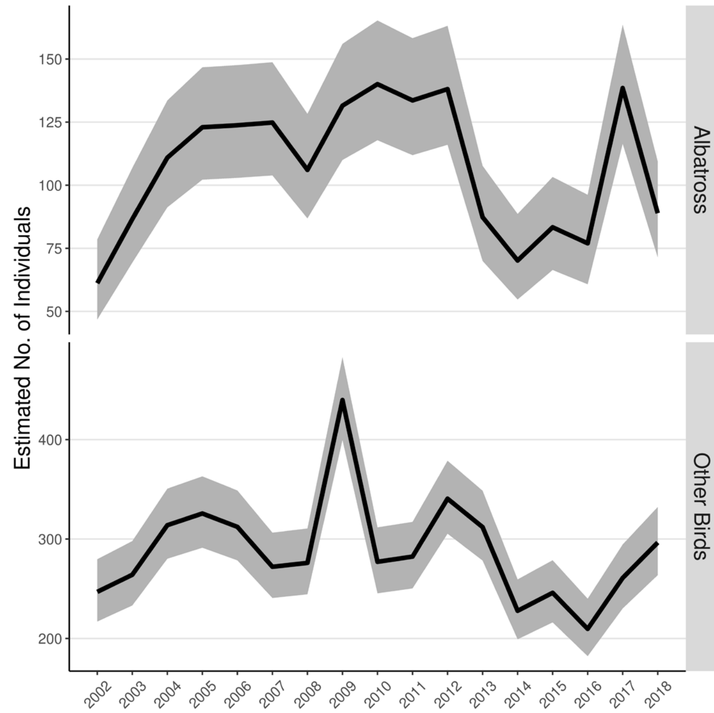

Figure 2. Total estimated seabird mortality (black line = number of individuals; gray ribbon = 95% CI) from all fisheries, 2002–18.

Notably, estimated bycatch of Brandt's cormorant from 2012–16 ranged from 13 to 18 birds per year. However, estimated bycatch of Brandt's cormorant increased to 53 birds in 2017 and 91 birds in 2018. This sudden increase is due, in part, to previously unavailable observations obtained in the California ridgeback prawn fishery in 2017 and 2018 (see Table 18). WCGOP began observering this fishery in 2017, and a large number of birds were observed taken in this fishery in the first two years of observation. Low observer coverage and lack of historical observations in the California ridgeback prawn fishery contributed to both the large estimates and large variance around estimates for Brandt's cormorant.

In all, 32 species or taxa have been observed as bycatch in at least one year during the 17-year period from 2002–18 (Table 4).

Seabird Bycatch in Hook-and-Line Fisheries

Groundfish fisheries using hook-and-line gear on the U.S. West Coast account for the majority of seabird bycatch among these fisheries. Hook-and-line fisheries were responsible for almost all of the albatross bycatch, the majority being black-footed albatross, as is shown by the overlapping lines and the bars touching the line in the top panel of Figure 3. The spatial distribution of observed seabird bycatch and observed fishing effort for fixed gear fisheries is shown in Figures 4 and 5. Albatross mortality in hook-and-line fisheries drives the time-series of seabird bycatch across all fisheries (Figures 2 and 3). As with the total mortality, hook-and-line mortality was at a near high in 2012 of 132 BFAL, dropping to a low of 65 birds in 2014, and then increasing again to a high of 135 BFAL in 2017 (Table 5). Laysan and short-tailed albatross mortality was less than one bird per year from 2013–18 (Table 5). There were an estimated three Laysan albatross mortalities in 2012, dropping to less than one estimated Laysan mortality each year from 2013–18. Short-tailed albatross mortality was estimated to be less than one bird per year for 2013–18.

Table 4. Estimated seabird mortality in U.S. West Coast fisheries, 2012–18. Estimates include both randomly and opportunistically sampled birds (see text for full explanation). Estimates for the entire time series can be found in the Supplemental Tables. LCL/UCL = lower/upper 95% confidence limit.

	2012		2013		2014		2015		2016		2017		2018	
Species	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**
Black-footed albatross	134.73	112.9–159.5	85.31	68.2–105.4	69.29	53.9–87.6	82.83	66–102.7	76.14	60–95.3	137.78	115.7–162.8	88.36	70.9–108.8
Laysan albatross	2.83	0.5–8.5	1.63	0.1–6.6	0.51	0–4.7	0.30	0–4.3	0.50	0–4.7	0.45	0–4.6	0.33	0–4.4
Short-tailed albatross	0.53	0–4.7	0.41	0–4.5	0.36	0–4.4	0.20	0–4.1	0.34	0–4.4	0.28	0–4.3	0.21	0–4.1
Leach’s storm-petrel	0.00	0–3.7	2.00	0.2–7.2	0.00	0–3.7	2.00	0.2–7.2	5.00	1.6–11.7	3.00	0.6–8.8	0.00	0–3.7
Storm-petrel, unidentified	0.00	0	2.04	0.3–7.3	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Pink-footed shearwater	8.88	4–16.9	5.80	2.1–12.8	5.43	1.9–12.3	6.45	2.5–13.7	5.23	1.8–12	5.53	1.9–12.4	5.95	2.2–13
Sooty shearwater	42.13	30.4–56.9	47.62	35.1–63.2	31.28	21.3–44.3	43.22	31.3–58.2	27.84	18.5–40.3	26.41	17.3–38.6	46.03	33.7–61.4
Shearwater, unidentified	58.57	44.5–75.6	52.51	39.3–68.8	50.34	37.4–66.3	50.03	37.1–66	37.77	26.7–51.9	45.27	33.1–60.5	38.72	27.5–53
Northern fulmar	20.51	12.6–31.5	59.45	45.3–76.6	11.50	5.8–20.3	19.34	11.7–30.1	16.21	9.3–26.2	11.15	5.6–19.9	8.68	3.9–16.7
Tubenose, unidentified	0.00	0–3.7	0.00	0–3.7	0.00	0–3.7	0.00	0–3.7	0.00	0–3.7	0.00	0–3.7	0.00	0–3.7
Common murre	11.93	6.2–20.9	16.96	9.9–27.2	11.31	5.7–20.1	18.34	10.9–28.9	14.53	8–24.2	20.16	12.3–31.1	16.02	9.2–26
Murre, unidentified	1.07	0–5.7	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Cassin’s auklet	0.00	0–3.7	2.00	0.2–7.2	2.00	0.2–7.2	0.00	0–3.7	1.00	0–5.6	2.00	0.2–7.2	0.00	0–3.7
Alcid, unidentified	0.76	0–5.1	0.58	0–4.8	0.55	0–4.8	0.30	0–4.3	0.51	0–4.7	0.40	0–4.5	0.32	0–4.3
Brandt’s cormorant	13.31	7.1–22.6	16.33	9.4–26.4	16.00	9.1–26	17.45	10.2–27.8	14.12	7.7–23.6	52.99	39.7–69.3	91.23	73.5–112
Double-crested cormorant	9.39	4.4–17.6	5.56	1.9–12.4	6.48	2.5–13.7	4.45	1.3–10.9	4.68	1.4–11.2	4.61	1.4–11.1	6.41	2.4–13.6
Cormorant, unidentified	14.74	8.2–24.4	11.28	5.7–20	10.49	5.1–19	8.52	3.8–16.5	11.60	5.9–20.4	10.12	4.9–18.5	12.95	6.9–22.2
California gull	1.57	0.1–6.5	0.47	0–4.6	1.40	0.1–6.3	0.20	0–4.1	0.35	0–4.4	0.31	0–4.3	0.21	0–4.1
Glaucous-winged gull	3.37	0.8–9.3	1.00	0–5.6	0.82	0–5.3	0.50	0–4.7	0.83	0–5.3	0.79	0–5.2	0.61	0–4.9
Arctic herring gull	10.35	5–18.8	5.68	2–12.6	1.41	0.1–6.3	0.89	0–5.4	1.50	0.1–6.4	1.44	0.1–6.3	1.11	0–5.8
Mew gull	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Ring-billed gull	1.56	0.1–6.5	0.44	0–4.6	0.39	0–4.5	0.21	0–4.1	0.34	0–4.4	0.28	0–4.3	0.21	0–4.1
Western gull	73.75	57.9–92.6	23.07	14.6–34.6	19.23	11.6–30	16.50	9.5–26.6	15.42	8.7–25.3	20.18	12.4–31.1	15.12	8.5–24.9
Gull, unidentified	38.43	27.3–52.7	29.72	20–42.5	29.77	20.1–42.6	30.53	20.7–43.4	26.35	17.3–38.5	27.75	18.4–40.2	23.74	15.2–35.4
Brown pelican	14.47	8–24.1	12.56	6.6–21.7	12.68	6.7–21.8	11.32	5.7–20.1	11.60	5.9–20.4	13.27	7.1–22.6	11.15	5.6–19.9
Common loon	2.94	0.6–8.7	3.10	0.7–8.9	3.57	0.9–9.6	2.86	0.6–8.6	2.91	0.6–8.6	3.03	0.6–8.8	2.57	0.4–8.1
Green-winged teal	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
White-winged scoter	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Red-necked phalarope	0.00	0	0.00	0	0.00	0	0.00	0	1.00	0–5.6	0.00	0	0.00	0
Seabird, unidentified	8.00	3.5–15.8	8.00	3.5–15.8	8.00	3.5–15.8	8.00	3.5–15.8	8.00	3.5–15.8	9.00	4.1–17.1	8.00	3.5–15.8
Warbler, unidentified	0.00	0–3.7	0.00	0–3.7	0.00	0–3.7	0.00	0–3.7	0.00	0–3.7	0.00	0–3.7	4.00	1.1–10.2
Bird, unidentified	4.88	1.6–11.5	5.84	2.1–12.8	5.16	1.7–11.9	4.82	1.5–11.4	2.82	0.5–8.5	3.17	0.7–9	3.45	0.8–9.4

Hook-and-line vessels also contribute to a large fraction of the nonalbatross mortality (Figure 3). Other (nonalbatross) seabirds also show an increase in estimated bycatch from about 100 birds in 2002 rising to about 220 seabirds in 2012, with a smaller peak in 2009. Mortality of other seabirds on hook-and-line vessels declined from roughly 210 in 2012 to a little more than 100 in 2018 (Figure 3).

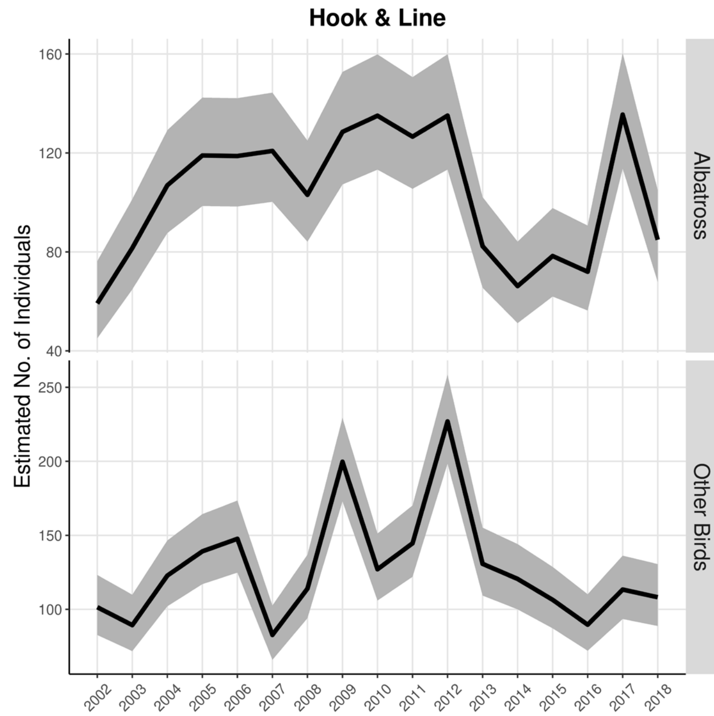

Figure 3. Total estimated seabird mortality from vessels using H&L gear observed by FOS. Dashed gray lines = total bird mortality from all gear types (same as Fig 2). Solid black lines = mortality from H&L gears. Shaded gray area = 95% CI. Table 5 reports the values.

After black-footed albatross, annual bird bycatch on hook-and-line vessels largely comprised, in decreasing order, shearwaters, gulls, and brown pelicans (Table 5). Pink-footed shearwaters make up a small but consistent portion of the bycatch in hook-and-line fisheries, with annual bycatch estimates between three and eight birds per year (2012–18; Table 5). A smaller number of other species are recorded annually, with a total of 23 species or taxa observed as bycatch in these hook-and-line fisheries over the 17-year period (Table 5).

Observed bycatch rates in hook-and-line fisheries are shown in Figure 6. These rates are calculated from the observed data and are not expanded to the whole fleet. Hook-and-line vessels fishing on the U.S. West Coast are not required to maintain or submit logbooks; therefore, hook counts for these fleets are not available. The international standard for reporting seabird bycatch on hook-and-line vessels is dead birds per 1,000 hooks. To compare bycatch rates in our fisheries to global fisheries, we present the observed bycatch rates based on observed number of hooks as well as observed landed catch. Landed catch is the only measure available as a fleetwide effort metric in these fisheries (Somers et al. 2019a). For context we also provide observer coverage rates (Figure 7), which are calculated as the weight of observed retained catch divided by the total weight of landed catch from fish sales receipts.

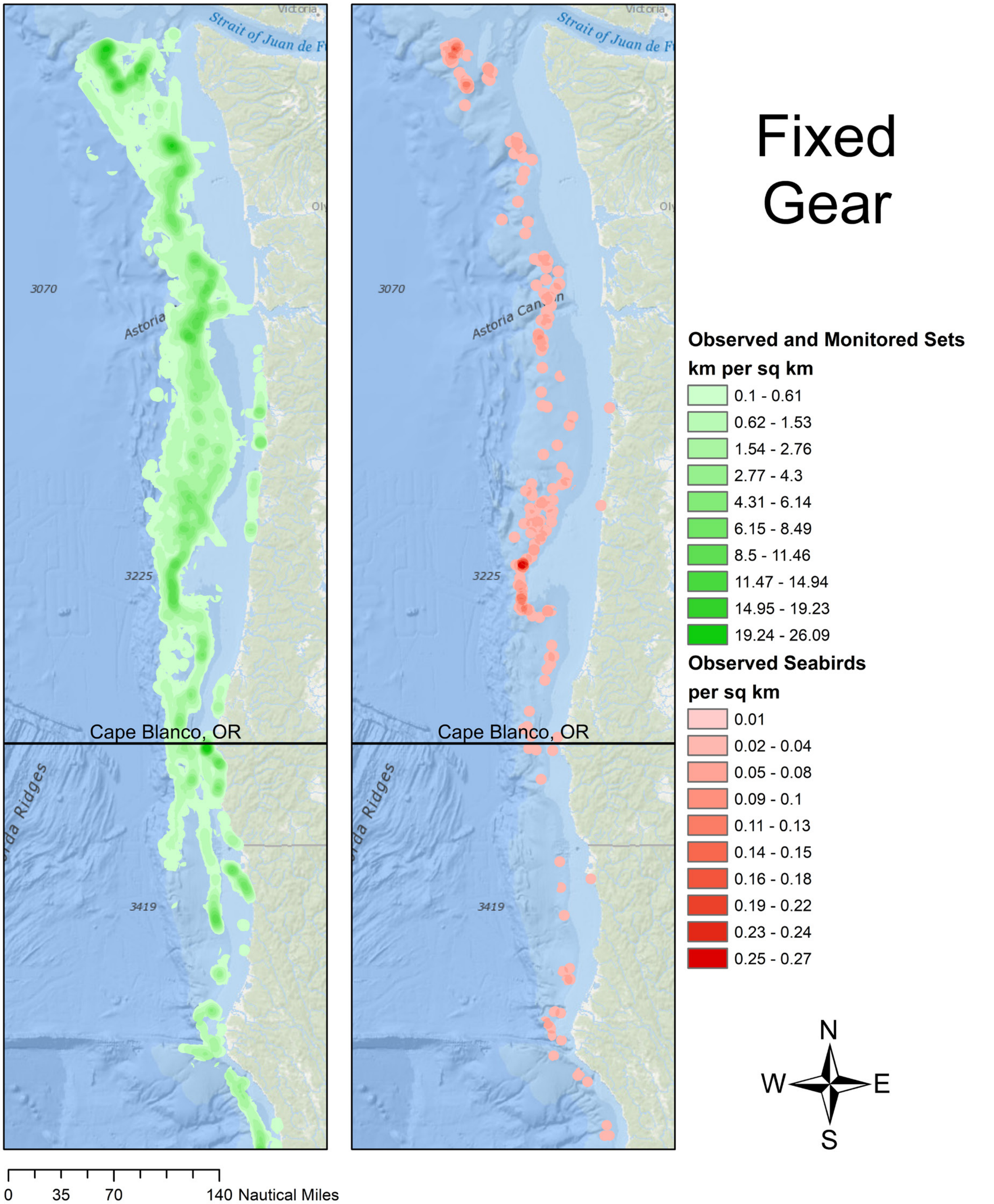

Figure 4. Spatial distribution of observed seabird bycatch (mt/km^2) and observed or monitored fishing gear sets on fixed gear vessels (H&L, pot) off the coasts of WA, OR, and Northern CA monitored by FOS (2002–18) and the PSMFC EM Program (2015–18). The 10 catch classifications were defined by excluding any zero values and then applying the Jenks natural breaks classification method. Cells (200 km^2) with <3 vessels were omitted to maintain confidentiality.

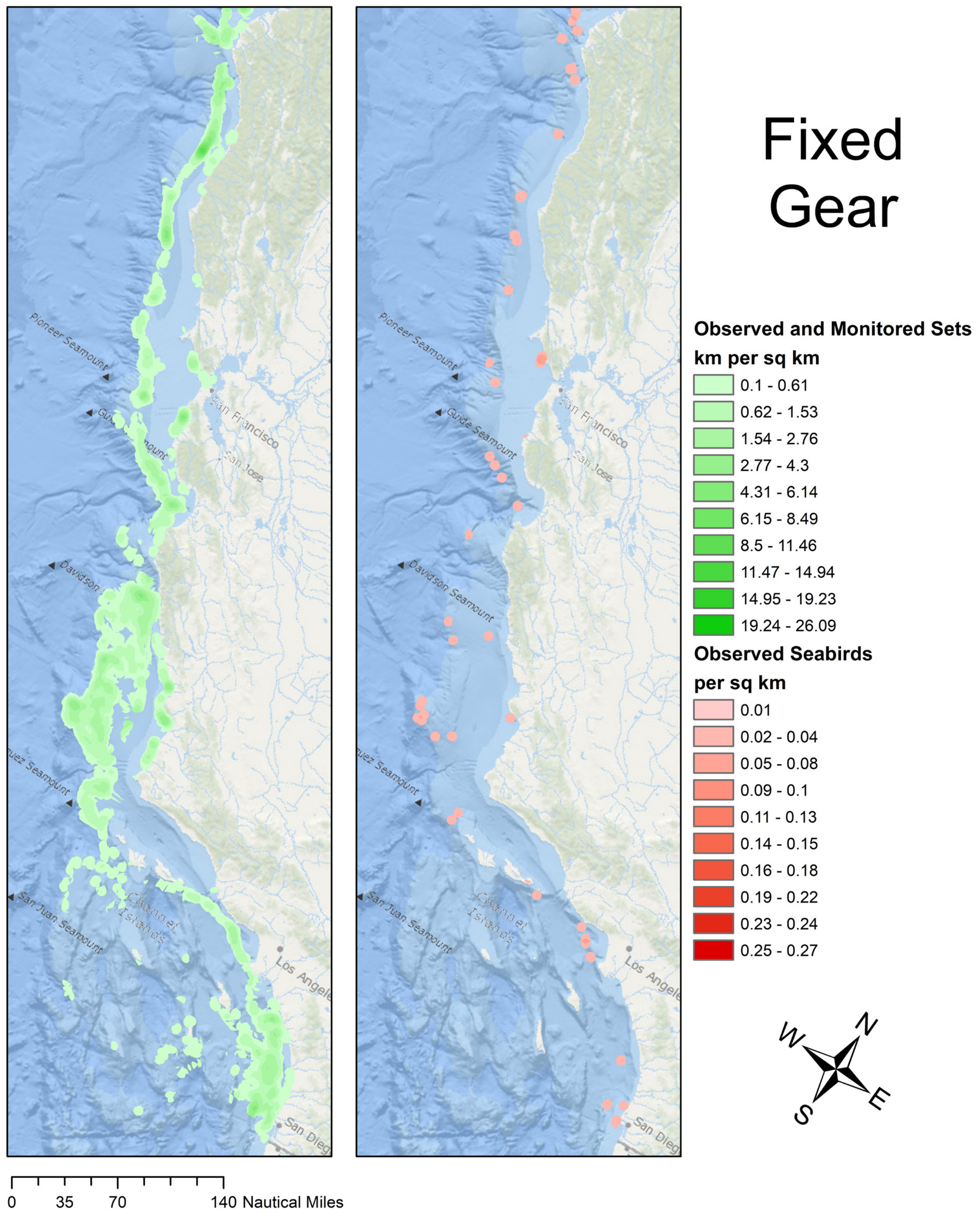

Figure 5. Spatial distribution of observed seabird bycatch (mt/km^2) and observed or monitored fishing gear sets on fixed gear vessels (H&L, pot) off the coast of Southern CA monitored by FOS (2002–18) and the PSMFC EM Program (2015–18). The 10 catch classifications were defined by excluding any zero values and then applying the Jenks natural breaks classification method. Cells (200 km^2) with <3 vessels were omitted to maintain confidentiality.

Table 5. Estimated seabird mortality in U.S. West Coast fisheries, 2012–18, for vessels fishing with hook-and-line gears. Estimates include both randomly and opportunistically sampled birds (see text for full explanation). Estimates for the entire time series can be found in the Supplemental Tables. LCL/UCL = lower/upper 95% confidence limit.

	2012		2013		2014		2015		2016		2017		2018	
Species	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**
Black-footed albatross	131.73	110.2–156.2	81.31	64.6–101	65.29	50.4–83.2	77.83	61.5–97.2	71.14	55.6–89.7	134.78	113–159.6	84.36	67.3–104.4
Laysan albatross	2.83	0.5–8.5	0.63	0–4.9	0.51	0–4.7	0.30	0–4.3	0.50	0–4.7	0.45	0–4.6	0.33	0–4.4
Short-tailed albatross	0.53	0–4.7	0.41	0–4.5	0.36	0–4.4	0.20	0–4.1	0.34	0–4.4	0.28	0–4.3	0.21	0–4.1
Pink-footed shearwater	7.80	3.3–15.5	4.16	1.2–10.5	4.21	1.2–10.5	4.36	1.3–10.8	4.42	1.3–10.9	4.57	1.4–11.1	4.43	1.3–10.9
Sooty shearwater	13.77	7.5–23.2	15.15	8.5–24.9	8.51	3.8–16.4	4.99	1.6–11.7	6.69	2.6–14	7.71	3.3–15.4	24.59	15.8–36.4
Shearwater, unidentified	38.94	27.7–53.2	29.85	20.1–42.7	28.11	18.7–40.6	29.46	19.8–42.2	15.72	8.9–25.6	25.32	16.4–37.3	18.26	10.9–28.8
Northern fulmar	10.48	5.1–19	2.45	0.4–7.9	4.50	1.4–11	2.34	0.4–7.8	2.20	0.3–7.5	5.15	1.7–11.9	1.68	0.2–6.7
Common murre	5.47	1.9–12.3	7.55	3.2–15.2	6.79	2.7–14.1	8.44	3.7–16.3	6.41	2.4–13.6	5.89	2.1–12.9	6.47	2.5–13.7
Alcid, unidentified	0.76	0–5.1	0.58	0–4.8	0.55	0–4.8	0.30	0–4.3	0.51	0–4.7	0.40	0–4.5	0.32	0–4.3
Brandt's cormorant	3.14	0.7–9	3.28	0.7–9.2	3.70	0.9–9.8	3.97	1.1–10.2	3.11	0.7–8.9	2.82	0.5–8.5	2.77	0.5–8.4
Double-crested cormorant	5.12	1.7–11.8	3.26	0.7–9.2	3.45	0.8–9.4	2.00	0.2–7.2	2.39	0.4–7.8	2.67	0.5–8.3	2.54	0.4–8.1
Cormorant, unidentified	4.48	1.3–10.9	3.69	0.9–9.8	3.45	0.8–9.4	2.10	0.3–7.4	2.49	0.4–8	2.85	0.6–8.5	2.50	0.4–8
California gull	1.57	0.1–6.5	0.47	0–4.6	0.38	0–4.4	0.20	0–4.1	0.35	0–4.4	0.31	0–4.3	0.21	0–4.1
Glaucous-winged gull	3.37	0.8–9.3	1.00	0–5.6	0.82	0–5.3	0.50	0–4.7	0.83	0–5.3	0.79	0–5.2	0.61	0–4.9
Arctic herring gull	10.35	5–18.8	1.68	0.2–6.7	1.41	0.1–6.3	0.89	0–5.4	1.50	0.1–6.4	1.44	0.1–6.3	1.11	0–5.8
Mew gull	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Ring-billed gull	1.56	0.1–6.5	0.44	0–4.6	0.39	0–4.5	0.21	0–4.1	0.34	0–4.4	0.28	0–4.3	0.21	0–4.1
Western gull	72.16	56.5–90.9	21.36	13.3–32.5	18.86	11.3–29.5	16.13	9.2–26.1	13.88	7.6–23.3	19.44	11.8–30.2	14.37	7.9–23.9
Gull, unidentified	27.34	18.1–39.7	16.99	9.9–27.2	15.44	8.7–25.3	12.93	6.9–22.1	11.02	5.5–19.7	14.98	8.4–24.7	11.72	6–20.6
Brown pelican	14.47	8–24.1	12.56	6.6–21.7	12.68	6.7–21.8	11.32	5.7–20.1	11.60	5.9–20.4	13.27	7.1–22.6	11.15	5.6–19.9
Common loon	2.94	0.6–8.7	3.10	0.7–8.9	3.57	0.9–9.6	2.86	0.6–8.6	2.91	0.6–8.6	3.03	0.6–8.8	2.57	0.4–8.1
Red-necked phalarope	0.00	0	0.00	0	0.00	0	0.00	0	1.00	0–5.6	0.00	0	0.00	0
Bird, unidentified	3.29	0.7–9.2	3.20	0.7–9.1	3.72	1–9.8	3.44	0.8–9.4	2.25	0.3–7.6	2.44	0.4–7.9	2.68	0.5–8.3

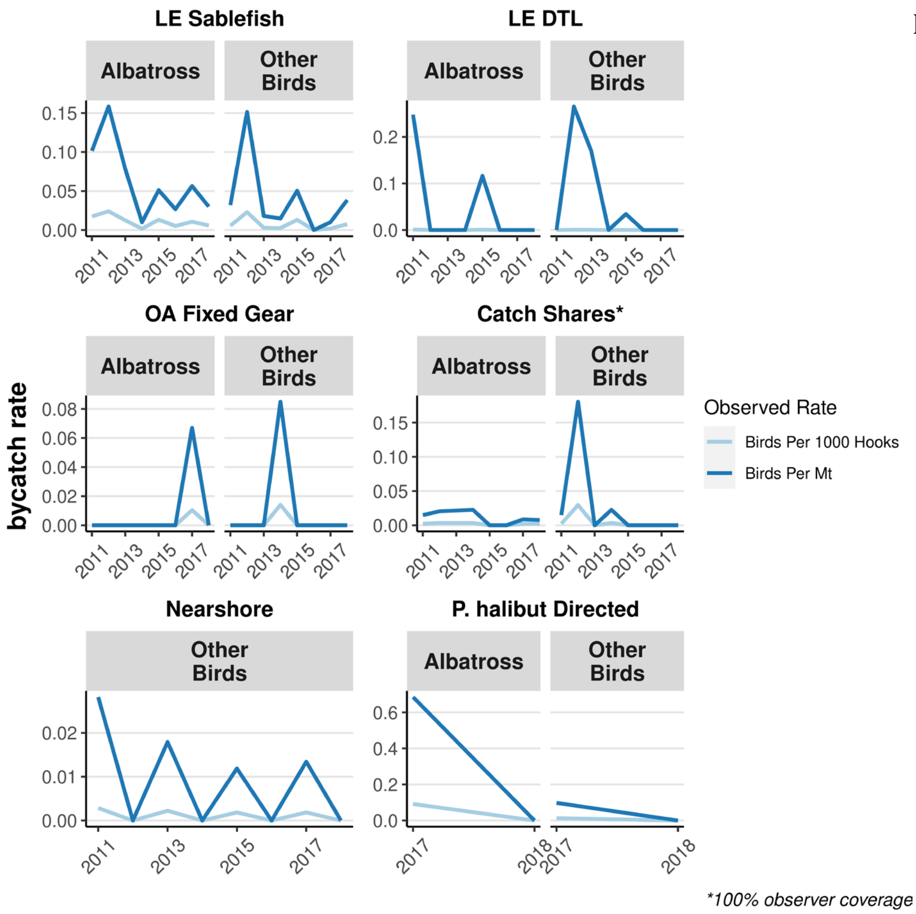

Figure 6. Albatross and other birds observed bycatch rates, as either number of observed birds per 1,000 hooks or per metric ton of landed targeted fish, from H&L fisheries observed by FOS. Birds/1,000 hooks is the international standard for reporting seabird bycatch. LE = limited entry, OA = open access, DTL = daily trip limits.

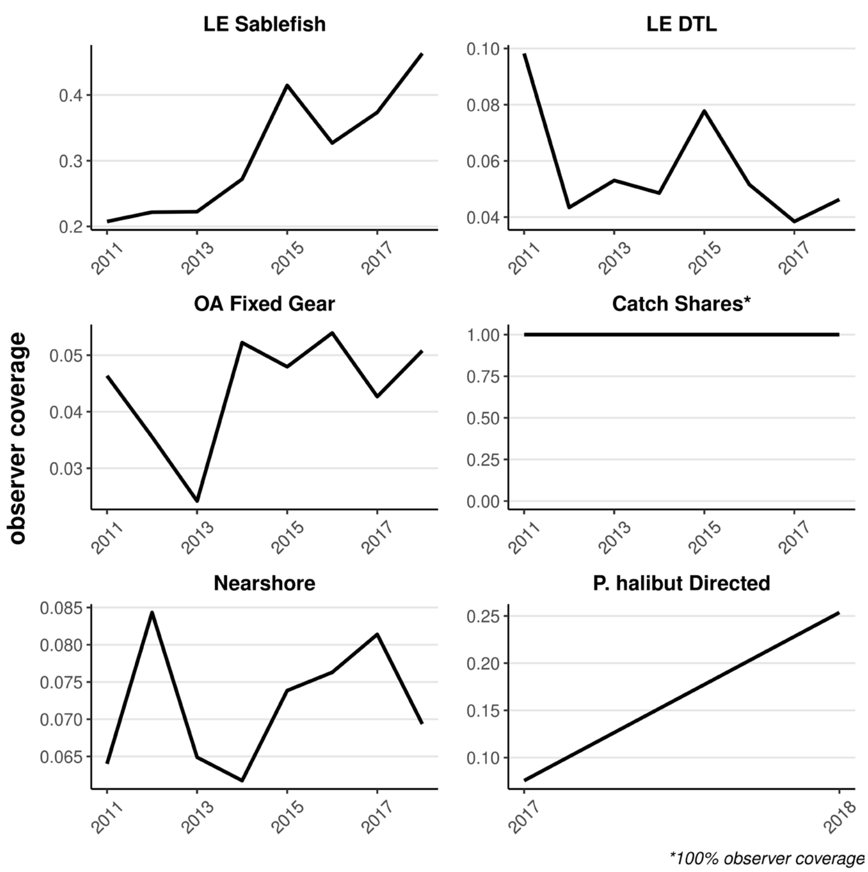

Figure 7. Observer coverage (observed retained fish [mt] ÷ total landed target catch [mt]) in H&L fisheries monitored by FOS. LE = limited entry, OA = open access, DTL = daily trip limits.

Limited entry sablefish

The limited entry sablefish endorsed vessels use longlines to target sablefish and deliver their catch to shore-based processors managed by a tiered-quota system. The fishing season is open from April through October.

Black-footed albatross were the main species caught in the LE sablefish endorsed fishery. Mean annual bycatch in this fishery over the last six-year period was 56 BFAL (Table 6). A single ESA-endangered short-tailed albatross was taken in the LE sablefish fishery in 2011 (Supplemental Table 3); this was the only such take of this species observed in any of the fisheries in this report. During the 2012 LE sablefish season, a single dead Laysan albatross was observed in a random species composition sample; this expanded to 1.88 birds in that set (Table 6), resulting in an estimated total of 2.83 individuals in 2012 in this fishery (Table 6).

Nonalbatross species comprise a small amount of seabird bycatch in the LE sablefish fishery. A total of 17 taxa have been observed as bycatch in the LE sablefish fishery over the 17-year period, primarily western gulls, shearwaters, and northern fulmars (Table 6).

Limited entry daily trip limits (LE DTL)

Limited entry daily trip limits (DTL) longline vessels target groundfish, primarily sablefish and thornyheads. These vessels have attained their annual sablefish quota limit and fish outside the normal LE sablefish season. Catch is delivered to shore-based processors or sold alive.

Shearwaters top the list of species caught in this fishery, followed by black-footed albatross, brown pelicans, and gulls (Table 7, Supplemental Table 4). Three or four pink-footed shearwaters are estimated caught each year, on average, in this fishery (Table 7).

Open access fixed gears

OA fixed gear vessels use a variety of fixed gear with hooks, including longlines, fishing poles, and stick gear. These vessels target non-nearshore groundfish and deliver their catch to shore-based processors.

Only two bird taxa have been reported from the OA fixed gear fishery: black-footed albatross and unidentified gulls (Table 8, Supplemental Table 5).

Catch share hook-and-line fisheries

Hook-and-line longline vessels that hold individual fishing quotas (IFQs) primarily target groundfish species, mainly sablefish, and deliver to shore-based processors. This fishery has 100% observer coverage; therefore, the observed bycatch is a complete census of these vessels.

Black-footed albatross, northern fulmars, mew gulls, western gulls, and unidentified gulls were observed as bycatch in this fishery (Table 9).

Table 6. Estimated seabird mortality in the U.S. West Coast limited entry sablefish endorsed fishery, 2012–18, for vessels fishing with hook-and-line gears. Estimates include both randomly and opportunistically sampled birds (see text for full explanation). Estimates for the entire time series can be found in the Supplemental Tables. LCL/UCL = lower/upper 95% confidence limit.

	2012		2013		2014		2015		2016		2017		2018	
Species	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**
Black-footed albatross	88.14	70.7–108.6	49.39	36.6–65.2	37.25	26.3–51.3	55.56	41.9–72.2	51.69	38.6–67.8	63.59	48.9–81.3	48.23	35.6–63.9
Laysan albatross	2.83	0.5–8.5	0.63	0–4.9	0.51	0–4.7	0.30	0–4.3	0.50	0–4.7	0.45	0–4.6	0.33	0–4.4
Short-tailed albatross	0.53	0–4.7	0.41	0–4.5	0.36	0–4.4	0.20	0–4.1	0.34	0–4.4	0.28	0–4.3	0.21	0–4.1
Pink-footed shearwater	4.09	1.1–10.4	0.81	0–5.2	0.69	0–5	0.41	0–4.5	0.67	0–5	0.63	0–4.9	0.48	0–4.6
Sooty shearwater	5.60	2–12.5	5.72	2–12.7	3.31	0.8–9.2	2.17	0.3–7.5	3.58	0.9–9.6	3.50	0.8–9.5	20.75	12.8–31.8
Shearwater, unidentified	3.00	0.6–8.8	2.07	0.3–7.3	2.12	0.3–7.4	14.40	7.9–24	2.12	0.3–7.4	1.82	0.2–6.9	1.47	0.1–6.4
Northern fulmar	10.48	5.1–19	2.45	0.4–7.9	2.12	0.3–7.4	2.34	0.4–7.8	2.20	0.3–7.5	5.15	1.7–11.9	1.68	0.2–6.7
Alcid, unidentified	0.76	0–5.1	0.58	0–4.8	0.55	0–4.8	0.30	0–4.3	0.51	0–4.7	0.40	0–4.5	0.32	0–4.3
Cormorant, unidentified	0.47	0–4.6	0.41	0–4.5	0.32	0–4.3	0.24	0–4.2	0.32	0–4.3	0.28	0–4.3	0.20	0–4.1
California gull	1.57	0.1–6.5	0.47	0–4.6	0.38	0–4.4	0.20	0–4.1	0.35	0–4.4	0.31	0–4.3	0.21	0–4.1
Glaucous-winged gull	3.37	0.8–9.3	1.00	0–5.6	0.82	0–5.3	0.50	0–4.7	0.83	0–5.3	0.79	0–5.2	0.61	0–4.9
Arctic herring gull	10.35	5–18.8	1.68	0.2–6.7	1.41	0.1–6.3	0.89	0–5.4	1.50	0.1–6.4	1.44	0.1–6.3	1.11	0–5.8
Ring-billed gull	1.56	0.1–6.5	0.44	0–4.6	0.39	0–4.5	0.21	0–4.1	0.34	0–4.4	0.28	0–4.3	0.21	0–4.1
Western gull	18.11	10.8–28.6	9.51	4.5–17.8	7.63	3.2–15.3	7.11	2.9–14.6	5.51	1.9–12.4	8.11	3.5–15.9	5.24	1.8–12
Gull, unidentified	8.37	3.7–16.3	2.45	0.4–7.9	3.43	0.8–9.4	3.57	0.9–9.6	2.88	0.6–8.6	3.36	0.8–9.3	1.94	0.2–7.1
Red-necked phalarope	0.00	0	0.00	0	0.00	0	0.00	0	1.00	0–5.6	0.00	0	0.00	0
Bird, unidentified	1.37	0.1–6.2	1.00	0–5.6	1.98	0.2–7.2	1.59	0.1–6.6	0.94	0–5.5	0.79	0–5.2	0.64	0–4.9

Table 7. Estimated seabird mortality in the U.S. West Coast limited entry daily trip limits fishery, 2012–18, for vessels fishing with hook-and-line gears. Estimates include both randomly and opportunistically sampled birds (see text for full explanation). Estimates for the entire time series can be found in the Supplemental Tables. LCL/UCL = lower/upper 95% confidence limit.

	2012		2013		2014		2015		2016		2017		2018	
Species	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**
Black-footed albatross	29.81	20.1–42.6	22.64	14.3–34.1	20.96	13–32	15.39	8.7–25.2	11.52	5.9–20.3	10.84	5.4–19.5	12.11	6.3–21.1
Pink-footed shearwater	3.71	0.9–9.8	3.35	0.8–9.3	3.52	0.9–9.5	3.95	1.1–10.2	3.76	1–9.9	3.94	1.1–10.2	3.95	1.1–10.2
Sooty shearwater	8.17	3.6–16	9.42	4.4–17.6	5.20	1.7–12	2.82	0.5–8.5	3.11	0.7–8.9	4.21	1.2–10.5	3.84	1–10
Shearwater, unidentified	35.93	25.2–49.8	27.78	18.4–40.2	25.99	17–38.1	15.06	8.4–24.8	13.61	7.4–23	13.25	7.1–22.5	14.07	7.7–23.6
Double-crested cormorant	5.12	1.7–11.8	3.26	0.7–9.2	3.45	0.8–9.4	2.00	0.2–7.2	2.39	0.4–7.8	2.67	0.5–8.3	2.54	0.4–8.1
Cormorant, unidentified	4.01	1.1–10.2	3.29	0.7–9.2	3.13	0.7–9	1.86	0.2–7	2.17	0.3–7.5	2.57	0.4–8.1	2.30	0.3–7.7
Western gull	6.15	2.3–13.3	4.99	1.6–11.7	3.96	1.1–10.2	2.29	0.3–7.7	2.61	0.5–8.2	3.36	0.8–9.3	3.15	0.7–9
Gull, unidentified	10.34	5–18.8	7.55	3.2–15.2	6.09	2.3–13.2	3.38	0.8–9.3	3.44	0.8–9.4	4.81	1.5–11.4	4.23	1.2–10.6
Brown pelican	8.36	3.7–16.2	5.71	2–12.7	5.85	2.1–12.9	5.50	1.9–12.4	6.36	2.4–13.5	6.55	2.5–13.8	6.33	2.4–13.5

Table 8. Estimated seabird mortality in the U.S. West Coast open access fixed gear fishery, 2012–18, for vessels fishing with hook-and-line gears. Estimates include both randomly and opportunistically sampled birds (see text for full explanation). Estimates for the entire time series can be found in the Supplemental Tables. LCL/UCL = lower/upper 95% confidence limit.

	2012		2013		2014		2015		2016		2017		2018	
Species	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**
Black-footed albatross	8.85	4–16.9	9.28	4.3–17.5	4.70	1.5–11.3	6.87	2.7–14.2	7.93	3.4–15.7	10.93	5.4–19.6	10.26	5–18.7
Gull, unidentified	4.69	1.5–11.2	4.67	1.4–11.2	4.05	1.1–10.3	4.13	1.2–10.4	3.31	0.8–9.2	4.16	1.2–10.5	3.49	0.8–9.5

Table 9. Estimated seabird mortality in the U.S. West Coast catch share fishery, 2012–18, for vessels fishing with hook-and-line gears. Estimates include both randomly and opportunistically sampled birds (see text for full explanation). Confidence limits are not given because catch share fisheries are 100% monitored and therefore represent a complete census of seabird mortality. For historical estimates, see the Supplemental Tables.

Species	2011	2012	2013	2014	2015	2016	2017	2018
Black-footed albatross	5.00	4.94	0.00	2.38	0.00	0.00	1.00	1.24
Northern fulmar	0.00	0.00	0.00	2.38	0.00	0.00	0.00	0.00
Mew gull	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Western gull	3.00	41.55	0.00	0.00	0.00	0.00	0.00	0.00
Gull, unidentified	1.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 10. Estimated seabird mortality in the U.S. West Coast nearshore fishery, 2012–18, for vessels fishing with hook-and-line gears. Estimates include both randomly and opportunistically sampled birds (see text for full explanation). Estimates for the entire time series can be found in the Supplemental Tables. LCL/UCL = lower/upper 95% confidence limit.

	2012		2013		2014		2015		2016		2017		2018	
Species	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**
Oregon														
Common murre	1.68	0.2–6.7	2.26	0.3–7.6	1.85	0.2–7	2.02	0.2–7.3	1.36	0.1–6.2	1.47	0.1–6.4	2.03	0.3–7.3
Western gull	1.83	0.2–7	2.39	0.4–7.8	2.11	0.3–7.4	2.29	0.3–7.7	1.69	0.2–6.7	3.05	0.6–8.8	2.34	0.4–7.8
Gull, unidentified	1.94	0.2–7.1	2.31	0.3–7.7	1.88	0.2–7	1.85	0.2–7	1.38	0.1–6.2	2.65	0.5–8.2	2.06	0.3–7.3
Bird, unidentified	1.93	0.2–7.1	2.20	0.3–7.5	1.74	0.2–6.8	1.85	0.2–7	1.31	0.1–6.1	1.65	0.1–6.7	2.04	0.3–7.3
California														
Common murre	3.79	1–9.9	5.28	1.8–12.1	4.94	1.6–11.6	6.42	2.5–13.6	5.05	1.6–11.7	4.43	1.3–10.9	4.44	1.3–10.9
Brandt's cormorant	3.14	0.7–9	3.28	0.7–9.2	3.70	0.9–9.8	3.97	1.1–10.2	3.11	0.7–8.9	2.82	0.5–8.5	2.77	0.5–8.4
Western gull	4.52	1.4–11	4.47	1.3–10.9	5.16	1.7–11.9	4.45	1.3–10.9	4.07	1.1–10.3	4.92	1.6–11.5	3.64	0.9–9.7
Brown pelican	6.10	2.3–13.2	6.84	2.7–14.2	6.83	2.7–14.2	5.82	2.1–12.8	5.24	1.8–12	6.73	2.6–14.1	4.81	1.5–11.4
Common loon	2.94	0.6–8.7	3.10	0.7–8.9	3.57	0.9–9.6	2.86	0.6–8.6	2.91	0.6–8.6	3.03	0.6–8.8	2.57	0.4–8.1

Nearshore

Nearshore fixed gear vessels use a variety of hook-and-line gear, including longline, fishing poles, and stick gear, to target nearshore rockfish and other nearshore species managed by state permits in Oregon and California. A subset of vessels also use pot gear, mainly to target California sheephead (*Semicossyphus pulcher*). Data from nearshore pot vessels are combined with data from other pot fisheries and presented in Seabird bycatch in pot gear fisheries. Catch is delivered to shore-based processors or sold live. Washington does not allow commercial nearshore fixed gear fishing.

Historically, WCGOP has split the nearshore fishery by state but combined hook-and-line with pot gears within states (Jannot et al. 2011, Somers et al. 2019a). However, our work here shows that seabird bycatch on hook-and-line gear is much greater than with pot gear (Tables 5 and 19). Therefore, we estimate seabird mortality separately for hook-and-line and pot gears by state.

Overall bycatch in the state-managed nearshore fisheries is low. The Oregon nearshore hook-and-line fishery has only caught common murres, western gulls, unidentified gulls, and unidentified birds (Table 10, Supplemental Table 7). In the California nearshore hook-and-line fishery, in addition to common murres and western gulls, observers have also recorded takes of Brandt's cormorant, brown pelican, and common loon (Table 10, Supplemental Table 7).

Pacific halibut fishery

Vessels with an International Pacific Halibut Commission-issued Pacific halibut permit use longline gear to fish for Pacific halibut (*Hippoglossus stenolepis*) during the annual openers. WCGOP began observing this fishery in 2017. In 2017, seven black-footed albatross and one shearwater were observed as takes, resulting in an estimated 48 BFAL and 10 shearwaters in 2017 (Table 11, Supplemental Table 8). No bird bycatch was observed in 2018, so the fleetwide estimates for these two species dropped in 2018 to 13 BFAL and three shearwaters (Table 11, Supplemental Table 8).

Table 11. Estimated seabird mortality in the Pacific halibut fishery, 2017–18, for vessels fishing with hook-and-line gears. Estimates include both randomly and opportunistically sampled birds (see text for full explanation). NWFSC started observing the P. halibut fishery in 2017. LCL/UCL = lower/upper 95% confidence limit.

	2017		2018	
Species	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**
Black-footed albatross	48.42	35.8–64.1	12.52	6.6–21.6
Shearwater, unidentified	10.26	5–18.7	2.72	0.5–8.3

Seabird Bycatch in Trawl Fisheries

Estimates indicate that potentially up to 45% of the global seabird bycatch occurs in trawl fisheries (Baker et al. 2007). The causes of seabird mortality in trawl fisheries can be broadly categorized into fatalities resulting from: a) collisions with net transponder cables, warp cables, or paravanes, and b) net entanglement, in particular, diving birds interacting with pelagic trawlers (Sullivan et al. 2006a, 2006b). Seabird collisions with trawl transponder or warp cables often go unwitnessed. Birds colliding with cables are not typically captured by the gear, which can result in unreported cryptic mortality not often accounted for in fisheries management (Bartle 1991, Melvin et al. 2011, Tamini et al. 2015). Seabirds in the air or on the water that strike a cable are rarely observed or recorded.

To better understand cryptic mortality on at-sea hake catcher–processor midwater trawl vessels, A-SHOP observers conducted a study of seabird cable strikes on these vessels from 2016–19. Seabird cable strikes have been documented on midwater trawl nets fishing for hake in the Washington and Oregon at-sea hake catcher–processor fleets (J. Jannot, unpublished data), as well as in similar trawl fisheries around the globe (Williams and Capdeville 1996, Melvin et al. 2011, Parker et al. 2013, Tamini et al. 2015). For the first time, the A–SHOP study allows us to estimate mortality from cable strikes in the at-sea hake catcher–processor fleet. We have added estimates of bycatch from cable strikes to our other estimates of seabird mortality in this report. A brief description of the special study is provided in Methods.

Because at least some portion of seabird bycatch in trawl fisheries is likely to go unreported, our estimates of seabird bycatch in trawl fisheries are biased to the low end, and estimates of seabird bycatch in trawl fisheries reported here should be considered an underestimate of the true numbers.

The majority of trawl seabird bycatch is north of Cape Blanco, Oregon, with some bycatch between Cape Blanco and Cape Mendocino, California (Figure 8). South of Cape Mendocino, trawl seabird bycatch is sparse and mainly concentrated near the mouth of San Francisco Bay and in the Southern California Bight near Santa Barbara and Ventura, California (Figure 9).

Sooty shearwaters are the most frequently observed species in trawl bycatch, followed by Brandt's cormorant, unidentified shearwaters, northern fulmars, unidentified gulls, and common murres (Table 12). A few black-footed albatross are observed each year, along with pink-footed shearwaters. Laysan albatross have been taken in the past in trawl fisheries (Supplemental Table 9). A smaller number of individuals from 16 other species or taxa have been observed in these trawl fisheries over the 17-year period (Table 12). In contrast to hook-and-line fisheries, trawl fisheries kill fewer albatross, only between two and seven black-footed albatross annually; these numbers include estimates from cable strikes on at-sea hake catcher–processor vessels (Figure 10, Table 12, Supplemental Table 9). In 2013, the only observed mortality of a Laysan albatross in trawl fisheries was recorded (Table 12).

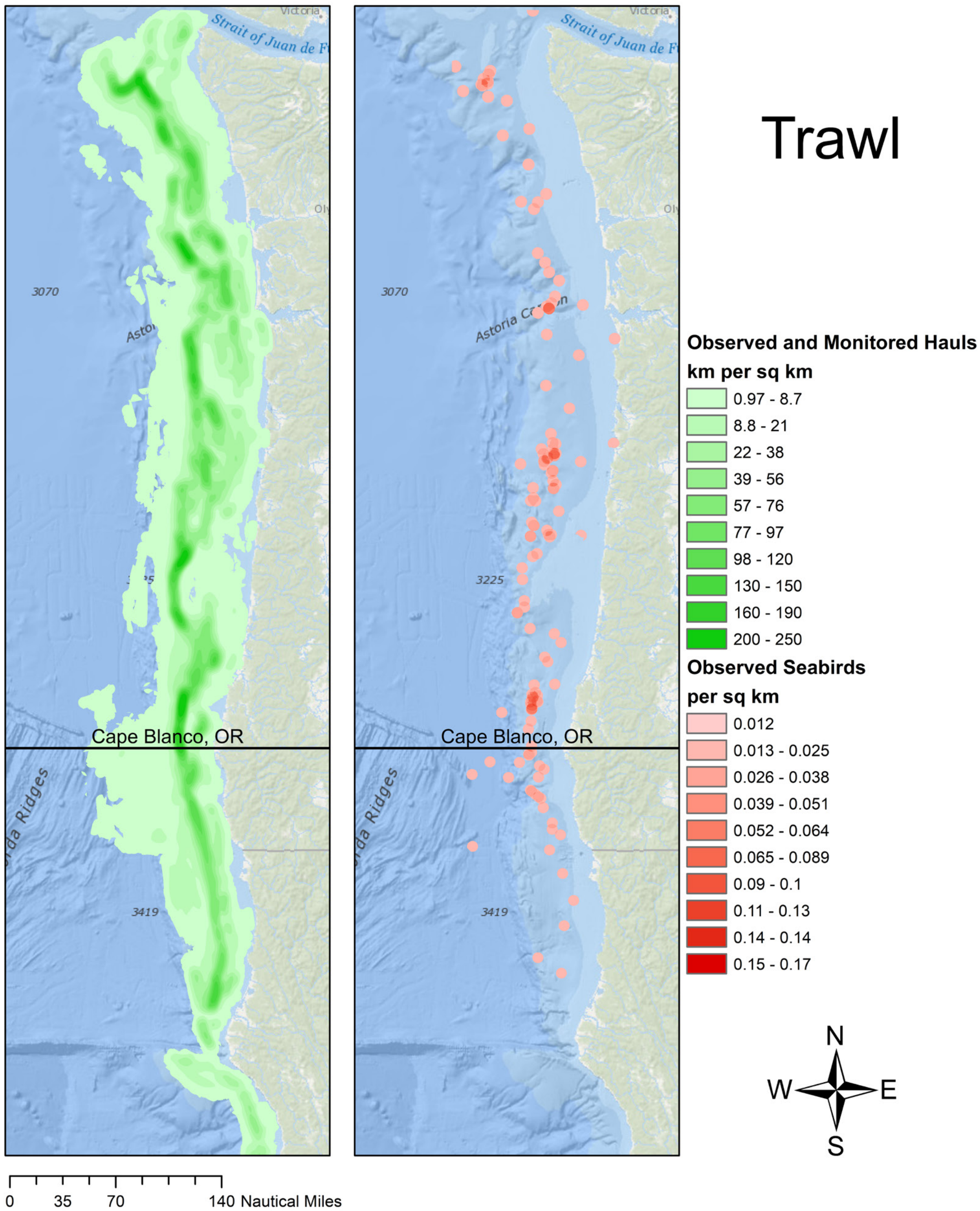

Figure 8. Spatial distribution of observed seabird bycatch (mt/km^2) and monitored fishing sets on bottom, midwater, and shrimp trawl vessels along the WA, OR, and Northern CA coasts observed by FOS (2002–18) and the PSMFC EM Program (2015–18). The 9 catch classifications were defined by excluding any zero values and then applying the Jenks natural breaks classification method. Cells (200 km^2) with <3 vessels were omitted to maintain confidentiality.

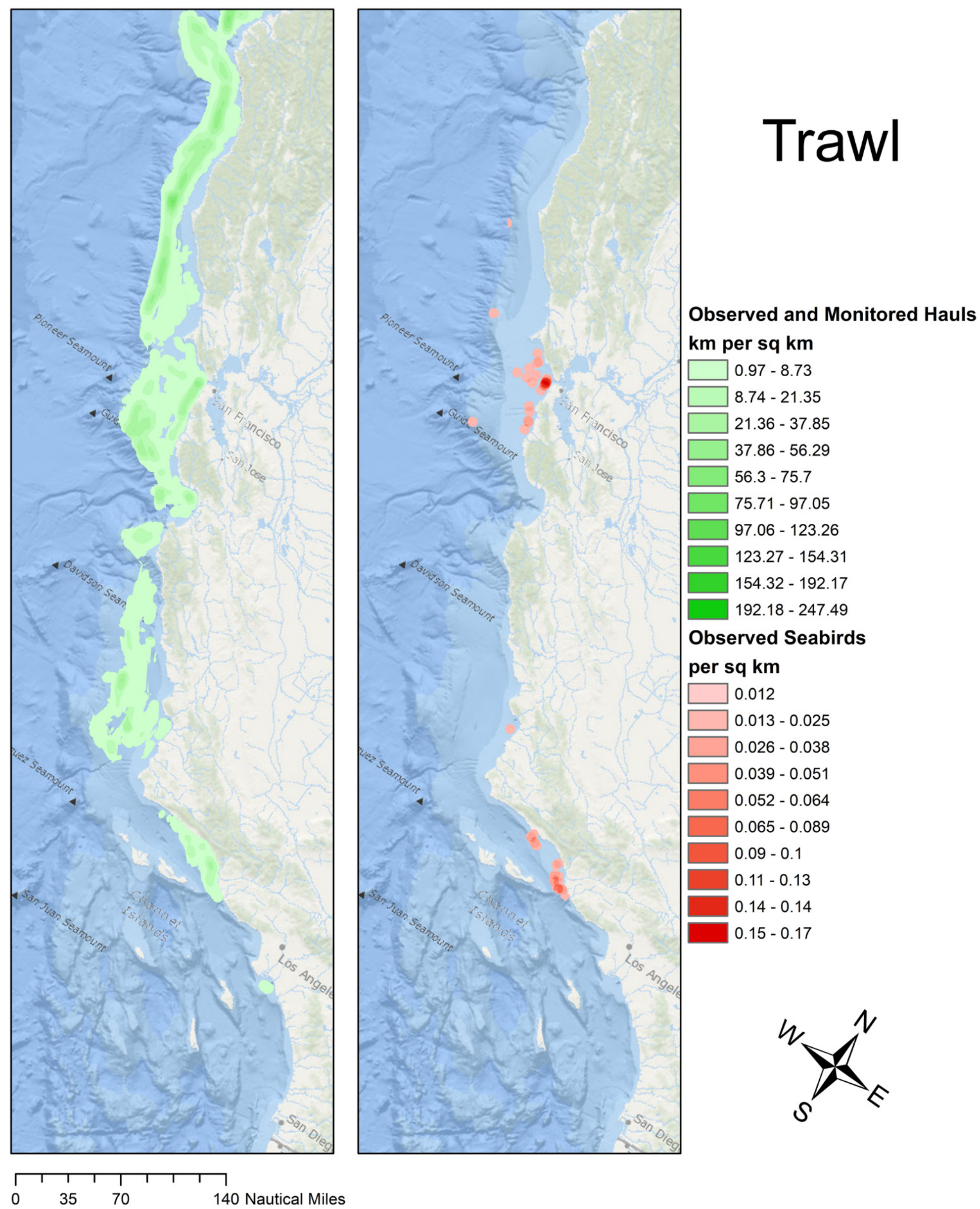

Figure 9. Spatial distribution of observed seabird bycatch (mt/km^2) and monitored fishing sets on bottom, midwater, and shrimp trawl vessels along the Southern CA coast observed by FOS (2002–18) and the PSMFC EM Program (2015–18). The 9 catch classifications were defined by excluding any zero values and then applying the Jenks natural breaks classification method. Cells (200 km^2) with <3 vessels were omitted to maintain confidentiality.

Table 12. Estimated seabird mortality in U.S. West Coast fisheries, 2012–18, for vessels fishing with trawl gears. Estimates include both randomly and opportunistically sampled birds (see text for full explanation). Estimates for the entire time series can be found in the Supplemental Tables. LCL/UCL = lower/upper 95% confidence limit.

	2012		2013		2014		2015		2016		2017		2018	
Species	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**
Black-footed albatross	3.00	0.6–8.8	4.00	1.1–10.2	3.00	0.6–8.8	5.00	1.6–11.7	6.00	2.2–13.1	3.00	0.6–8.8	4.00	1.1–10.2
Laysan albatross	0.00	0	1.00	0–5.6	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Leach's storm-petrel	0.00	0–3.7	2.00	0.2–7.2	0.00	0–3.7	2.00	0.2–7.2	5.00	1.6–11.7	3.00	0.6–8.8	0.00	0–3.7
Storm-petrel, unidentified	0.00	0	1.04	0–5.6	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Pink-footed shearwater	1.08	0–5.7	1.64	0.1–6.7	1.22	0.1–5.9	2.09	0.3–7.4	0.81	0–5.2	0.96	0–5.5	1.53	0.1–6.5
Sooty shearwater	28.36	18.9–40.9	32.48	22.3–45.7	22.77	14.4–34.2	38.22	27.1–52.4	21.16	13.1–32.3	18.71	11.2–29.3	21.44	13.3–32.6
Shearwater, unidentified	19.63	11.9–30.4	22.66	14.3–34.1	22.23	14–33.6	20.58	12.7–31.6	22.05	13.8–33.4	19.96	12.2–30.8	20.46	12.6–31.4
Northern fulmar	10.03	4.8–18.4	57.00	43.2–73.9	7.00	2.8–14.4	17.00	9.9–27.2	14.01	7.7–23.5	6.00	2.2–13.1	7.00	2.8–14.4
Tubenose, unidentified	0.00	0–3.7	0.00	0–3.7	0.00	0–3.7	0.00	0–3.7	0.00	0–3.7	0.00	0–3.7	0.00	0–3.7
Common murre	6.46	2.5–13.7	9.41	4.4–17.6	4.52	1.4–11	9.90	4.7–18.3	8.13	3.5–15.9	14.26	7.8–23.8	9.55	4.5–17.8
Murre, unidentified	1.07	0–5.7	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Cassin's auklet	0.00	0–3.7	2.00	0.2–7.2	2.00	0.2–7.2	0.00	0–3.7	1.00	0–5.6	2.00	0.2–7.2	0.00	0–3.7
Alcid, unidentified	0.00	0–3.7	0.00	0–3.7	0.00	0–3.7	0.00	0–3.7	0.00	0–3.7	0.00	0–3.7	0.00	0–3.7
Brandt's cormorant	5.71	2–12.7	9.24	4.3–17.4	4.26	1.2–10.6	4.92	1.6–11.5	5.51	1.9–12.4	46.26	33.9–61.6	83.80	66.8–103.8
Cormorant, unidentified	3.32	0.8–9.2	3.10	0.7–8.9	1.00	0–5.6	1.06	0–5.7	2.82	0.5–8.5	3.47	0.8–9.5	2.56	0.4–8.1
California gull	0.00	0	0.00	0	1.02	0–5.6	0.00	0	0.00	0	0.00	0	0.00	0
Arctic herring gull	0.00	0	4.00	1.1–10.2	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Western gull	1.59	0.1–6.6	1.71	0.2–6.8	0.38	0–4.4	0.37	0–4.4	1.54	0.1–6.5	0.75	0–5.1	0.75	0–5.1
Gull, unidentified	11.09	5.6–19.8	12.73	6.7–21.9	14.33	7.9–23.9	17.60	10.4–28	15.34	8.6–25.2	12.77	6.8–21.9	11.02	5.5–19.7
Green-winged teal	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
White-winged scoter	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Seabird, unidentified	8.00	3.5–15.8	8.00	3.5–15.8	8.00	3.5–15.8	8.00	3.5–15.8	8.00	3.5–15.8	9.00	4.1–17.1	8.00	3.5–15.8
Warbler, unidentified	0.00	0–3.7	0.00	0–3.7	0.00	0–3.7	0.00	0–3.7	0.00	0–3.7	0.00	0–3.7	4.00	1.1–10.2
Bird, unidentified	1.59	0.1–6.6	2.65	0.5–8.2	1.44	0.1–6.3	1.38	0.1–6.2	0.57	0–4.8	0.73	0–5.1	0.77	0–5.2

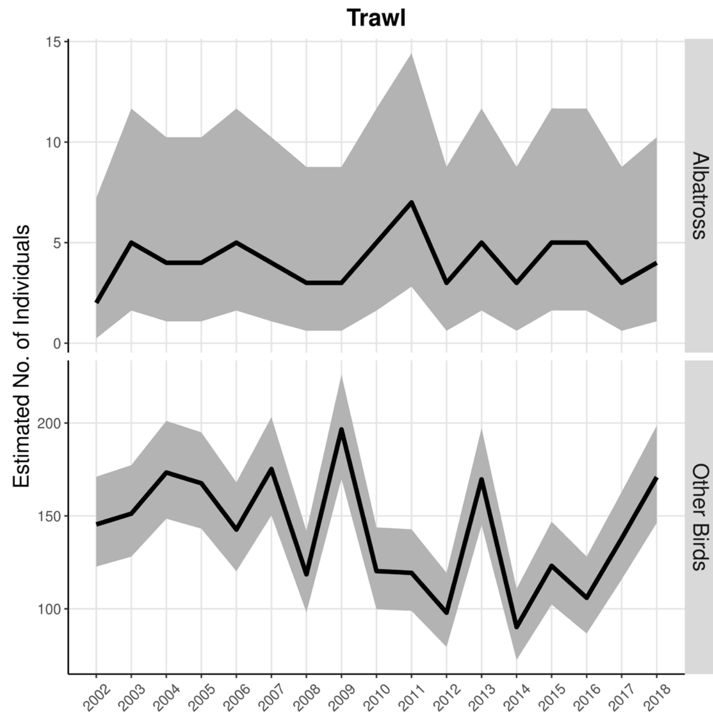

Figure 10. Total estimated seabird mortality from vessels using bottom, midwater, or shrimp trawl gear observed by FOS. Solid black lines = mortality from trawl gears. Gray band = 95% CI. Values are reported in Table 12.

At-sea hake fisheries

The at-sea hake fishery comprises three separate sectors. At-sea catcher–processors use midwater trawl nets to catch and process Pacific hake at sea. Catcher vessels use midwater trawl nets to catch hake and deliver unsorted catch to mothership processors at sea, where it is sorted and processed. At-sea Native American tribal vessels use midwater trawl nets to catch and process hake at sea. The tribes must operate within defined boundaries in waters off northwest Washington. Seabird bycatch from at-sea tribal fisheries is *not included* in this report.

The mortality of black-footed albatross was estimated to be three to four birds annually during 2012–18 (Table 13). The most frequently caught nonalbatross species on these vessels were shearwaters and northern fulmars, followed by gulls and common murres (Table 13). From one to a few individuals of eight other taxa were observed taken annually on at-sea catcher–processor vessels (Table 13, Supplemental Table 10).

Albatross have not been observed taken on hake catcher vessels delivering to motherships at sea (Table 14, Supplemental Table 11). Seabird bycatch on these vessels is rarely observed, with only one to a few northern fulmars, common murres, Cassin's auklets, and unidentified birds observed taken on these vessels in some, but not all, years (Table 14).

Table 13. Estimated seabird mortality (number of birds) in U.S. West Coast at-sea hake catcher–processor vessels fishing with midwater trawl gear, 2012–18. Estimates include both randomly and opportunistically sampled birds (see text for full explanation). Estimates for the entire time series can be found in the Supplemental Tables. Confidence limits are not given because at-sea fisheries are 100% observed and therefore represent a complete census of seabird mortality.

Species	2012	2013	2014	2015	2016	2017	2018
Black-footed albatross	3.00	4.00	3.00	3.00	4.00	3.00	4.00
Leach's storm-petrel	0.00	2.00	0.00	2.00	2.00	2.00	0.00
Sooty shearwater	0.00	1.00	0.00	0.00	0.00	0.00	0.00
Shearwater, unidentified	18.00	21.00	18.00	18.00	20.00	18.00	18.00
Northern fulmar	7.00	57.00	7.00	17.00	14.01	6.00	7.00
Tubenose, unidentified	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Common murre	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Cassin's auklet	0.00	2.00	0.00	0.00	0.00	2.00	0.00
Alcid, unidentified	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Arctic herring gull	0.00	4.00	0.00	0.00	0.00	0.00	0.00
Gull, unidentified	10.00	11.00	10.00	14.00	14.00	12.00	10.00
Seabird, unidentified	8.00	8.00	8.00	8.00	8.00	8.00	8.00
Warbler, unidentified	0.00	0.00	0.00	0.00	0.00	0.00	4.00
Bird, unidentified	0.00	1.00	1.00	0.00	0.00	0.00	0.00

Table 14. Estimated seabird mortality (number of birds) in U.S. West Coast at-sea hake catcher vessels fishing with midwater trawl gear and delivering to motherships, 2012–18. Estimates include both randomly and opportunistically sampled birds (see text for full explanation). Estimates for the entire time series can be found in Table 10. Confidence limits are not given because at-sea fisheries are 100% observed and therefore represent a complete census of seabird mortality.

Species	2012	2013	2014	2015	2016	2017	2018
Northern fulmar	2.00	0.00	0.00	0.00	0.00	0.00	0.00
Common murre	0.00	0.00	0.00	2.00	0.00	0.00	0.00
Cassin's auklet	0.00	0.00	2.00	0.00	1.00	0.00	0.00
Bird, unidentified	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Catch share trawl fisheries

Catch share bottom trawl vessels use nets to catch a variety of nonhake groundfish species. Catch is delivered to shore-based processors. From 2002–10, the LE bottom trawl vessels were managed under trip limits and annual catch limits, and observer coverage rate varied from 10 to 25% of landings. Since 2011, the catch share program requires bottom trawl vessels to possess an individual fishing quota (IFQ) for all IFQ species landed and discarded at sea. The catch share program also requires 100% observer coverage on all trips, unless vessels are participating in the exempted fishing permit (EFP) program that allows vessels to carry electronic monitoring (EM) equipment in lieu of an observer.

Some catch share vessels use midwater trawl nets to target midwater nonhake species, typically rockfish. Vessels must possess quota for all landed and discarded IFQ species. Landings of Pacific hake from these vessels are less than 50% (by weight) of total trip landings. Catch is delivered to shore-based processors.

Because the limited entry trawl program was converted to catch share in 2011, any seabird bycatch observed on vessels fishing in the limited entry California halibut fishery (see below) since 2011 were included with the catch share trawl estimates shown here. Very little effort occurred in this fishery from 2011–13, and no activity in this fishery since 2013.

In 2017, a single unidentified seabird was recorded as bycatch by the EM equipment on a catch share vessel fishing midwater trawl gear delivering Pacific hake shoreside. Because crew are required to present all seabirds to the camera for documentation on EM vessels, these vessels are considered to have a complete census of seabird bycatch.

Both black-footed and Laysan albatross mortalities have been observed on catch share trawl vessels: one black-footed albatross was taken in 2004 under the limited entry program (Supplemental Table 12). Two black-footed albatross were killed in 2015 and one in 2016 under the catch share program. One Laysan albatross was killed in 2013 under catch share management (Table 15). The most frequently caught nonalbatross taxa on these vessels were Leach's and unidentified storm-petrels, followed by, in decreasing numbers, sooty shearwaters, unidentified murres, northern fulmars, and gulls (Table 15, Supplemental Table 12).

California halibut fisheries

Limited entry (LE) California halibut trawl vessels use bottom trawl nets to target California halibut. Fishers must possess a state California halibut permit and an LE federal trawl groundfish permit. The LE trawl program was converted to catch share in 2011, and thus LE California halibut bycatch estimates since 2011 are included with catch share trawl estimates (Table 15; see Supplemental Table 13 for historical estimates of LE California halibut seabird bycatch). California halibut trawl participants that do not hold an LE federal groundfish trawl permit can still operate under open access (OA) privileges if they possess a state California halibut permit. In both cases, catch is delivered to shore-based processors. The 2010 LE California halibut estimates are included with the 2010 OA values to maintain confidentiality (Supplemental Table 13).

Albatross have not been observed as bycatch in California halibut fisheries (Table 16, Supplemental Tables 12 and 13). Bycatch of Brandt's cormorant has increased in recent years in the OA California halibut fishery, from about five in 2014, 2015, and 2016, to 11 in 2017, and 22 in 2018. Common murres are also a frequently caught species in the OA California halibut fishery, followed by unidentified cormorants, western gulls, and unidentified birds (Table 16).

Table 15. Estimated seabird mortality (number of birds) in the U.S. West Coast catch share fishery, 2012–18, for vessels fishing with trawl gears. Estimates include both randomly and opportunistically sampled birds (see text for full explanation). Estimates for the entire time series can be found in the Supplemental Tables. LCL/UCL = lower/upper 95% confidence limit.

	2012		2013		2014		2015		2016		2017	
Species	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**
Black-footed albatross	0.00	0	0.00	0	0.00	0	2.00	0	1.00	0	0.00	0
Laysan albatross	0.00	0	1.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Leach's storm-petrel	0.00	0	0.00	0	0.00	0	0.00	0	3.00	0	1.00	0
Storm-petrel, unidentified	0.00	0	1.04	0	0.00	0	0.00	0	0.00	0	0.00	0
Sooty shearwater	0.00	0	2.05	0	0.00	0	0.00	0	0.00	0	0.00	0
Northern fulmar	1.03	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Common murre	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Murre, unidentified	1.07	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Cassin's auklet	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
California gull	0.00	0	0.00	0	1.02	0	0.00	0	0.00	0	0.00	0
Gull, unidentified	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Green-winged teal	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
White-winged scoter	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Seabird, unidentified	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	1.00	0

Table 16. Estimated seabird mortality (number of birds) in U.S. West Coast open access (OA) California halibut vessels fishing with trawl gears, 2012–18. Estimates include both randomly and opportunistically sampled birds (see text for full explanation). Estimates for the limited entry (LE) California halibut fishery are included in Table 15. Estimates for the entire time series, including historical estimates for both LE and OA California halibut fisheries, can be found in the Supplemental Tables. LCL/UCL = lower/upper 95% confidence limit.

	2012		2013		2014		2015		2016		2017		2018	
Species	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**
Common murre	4.46	0–16.2	7.41	0.2–24.5	2.52	0.1–8.6	5.90	3.1–12.9	6.13	2.1–13.4	12.26	5.3–28.7	7.55	2.2–20.4
Brandt's cormorant	5.71	1.3–13	9.24	3–19.3	4.26	2.2–7.1	4.92	2.7–8	5.51	2.7–9.5	11.19	5.9–17.7	22.38	18.6–27.2
Cormorant, unidentified	3.32	0–14.3	3.10	0–12.9	1.00	0–4	1.06	0–3.9	2.82	1–7.8	3.47	1–10.2	2.56	0–9.3
Western gull	1.59	0–5.7	1.71	0–6.8	0.38	0–1.5	0.37	0–1.3	1.54	1–2.9	0.75	0–2.4	0.75	0–2.4
Bird, unidentified	1.59	0–6	1.65	0–6.1	0.44	0–1.9	1.38	1–2.3	0.57	0–1.9	0.73	0–2.3	0.77	0–2.6

Open access pink shrimp fisheries (WA, OR, CA)

Each of the three U.S. West Coast states operates and manages pink shrimp trawl fisheries in their state waters by issuing state-specific pink shrimp permits. Pink shrimp vessels use shrimp trawl nets to target pink shrimp. Catch is delivered to shore-based processors.

The only bird species observed caught in the California pink shrimp fishery has been pink-footed shearwaters (Table 17). Sooty shearwater is the main species recorded in Washington and Oregon pink shrimp fisheries (Table 17, Supplemental Table 14).

California ridgeback prawn fishery

The California ridgeback prawn trawl fishery is managed by prawn permits issued by the state of California. Vessels catch a variety of prawn and shrimp species for shoreside delivery. WCGOP began observing this fishery in 2017.

In 2018, five Brandt's cormorants were recorded as bycatch in this fishery. Given the low observer coverage in this fishery, the mortality estimate for Brandt's cormorant is quite high: 35 in 2017 (LCI = 12, UCI = 70) and 61 in 2018 (LCI = 23, UCI = 125; Table 18).

California sea cucumber fishery

The California sea cucumber fishery is managed by sea cucumber permits issued by the state of California. Vessels use trawl gears to catch sea cucumbers off the coast of California. WCGOP began observing this fishery in 2017. No bird mortalities were observed in the sea cucumber fishery during in 2017. In 2018, we observed less than three vessels, and therefore bycatch data are not reported to maintain confidentiality.

Seabird bycatch in pot gear fisheries

The vessels using pot gear to catch groundfish are active in the same fisheries described above for hook-and-line vessels. To protect confidentiality, we cannot report seabird bycatch with pot gears stratified by fishery. To date, seabird mortalities have been observed on vessels fishing with pot gear in catch share (including vessels using electronic monitoring), limited entry sablefish, and Oregon and California nearshore fisheries.

Most of the pot gear bycatch is cormorants, although a single black-footed albatross was taken in these fisheries in 2014 (Table 19, Supplemental Table 16).

Table 17. Estimated seabird mortality (number of birds) in U.S. West Coast open access (OA) pink shrimp vessels fishing with shrimp trawl gears, 2012–18. WCGOP began observing pink shrimp fisheries in OR and CA in 2004 and in WA in 2010. Estimates include both randomly and opportunistically sampled birds (see text for full explanation). Estimates for the entire time series can be found in the Supplemental Tables. LCL/UCL = lower/upper 95% confidence limit.

	2012		2013		2014		2015		2016		2017		2018	
Species	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**
Washington														
Sooty shearwater	21.34	17–27.6	8.83	3.1–16.8	13.44	5–25.9	26.78	12.4–43.8	11.11	4.9–19.6	9.11	3.9–15.2	9.09	3.6–16
Gull, unidentified	1.09	0–3.6	1.73	0–5.9	4.33	1.2–11.6	3.60	0.1–10.8	1.33	0–4.5	0.77	0–2.6	1.02	0–3.3
Oregon														
Sooty shearwater	7.02	2.5–13.5	20.61	16.2–27	9.32	3.2–18.3	11.45	4.4–21.6	10.05	4.4–17.8	9.60	4–16.8	12.35	5.7–21.1
Shearwater, unidentified	1.63	0–5	1.66	0–5.2	4.23	2.1–8.1	2.58	0.1–7.4	2.05	0.2–5.5	1.96	0.2–5.4	2.46	0.3–6.5
California														
Pink-footed shearwater	1.08	0–3.7	1.64	0–5.6	1.22	0–3.9	2.09	0–6.4	0.81	0–2.5	0.96	0–3.1	1.53	0–4.9

Table 18. Estimated seabird mortality (number of birds) on California ridgeback prawn vessels fishing with trawl gears, 2017–18. FOS began observing the California ridgeback prawn fishery in 2017. Estimates include both randomly and opportunistically sampled birds (see text for full explanation). LCL/UCL = lower/upper 95% confidence limit.

	2017		2018	
Species	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**
Brandt's cormorant	35.06	12.1–69.8	61.42	23.4–125.6

Table 19. Estimated seabird mortality (number of birds) in U.S. West Coast pot fisheries, 2012–18. Estimates include both randomly and opportunistically sampled birds (see text for full explanation). Estimates for the entire time series can be found in the Supplemental Tables. LCL/UCL = lower/upper 95% confidence limit.

	2012		2013		2014		2015		2016		2017		2018	
Species	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**	**Estimate**	**LCL–UCL**
Black-footed albatross	0.00	0	0.00	0	1.00	0–5.6	0.00	0	0.00	0	0.00	0	0.00	0
Storm-petrel, unidentified	0.00	0	1.00	0–5.6	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Northern fulmar	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0
Brandt's cormorant	4.46	1.3–10.9	3.81	1–10	8.03	3.5–15.8	8.57	3.8–16.5	5.49	1.9–12.4	3.91	1–10.1	4.65	1.4–11.2
Double-crested cormorant	4.27	1.2–10.6	2.30	0.3–7.7	3.03	0.6–8.8	2.46	0.4–7.9	2.29	0.3–7.7	1.94	0.2–7.1	3.86	1–10
Cormorant, unidentified	6.94	2.8–14.3	4.49	1.3–10.9	6.03	2.2–13.1	5.36	1.8–12.2	6.29	2.4–13.5	3.80	1–9.9	7.89	3.4–15.6
Gull, unidentified	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	1.00	0–5.6

Seabird Bycatch Mitigation and Avoidance

In response to the 2012 U.S. Fish and Wildlife Service Biological Opinion regarding short-tailed albatross interactions with U.S. West Coast fisheries, PFMC and NOAA implemented a regulation requiring the use of streamer lines on nontribal longline vessels 55 feet or longer in December 2015 (USOFR 2015). This rule requires:

- Commercial, nontribal, longline vessels 16.76 m (55 ft) and longer to deploy one or two streamer lines during fishing, depending on gear configuration.
- Streamer lines must meet technical specifications and be available for inspection.
- Rough weather exemption is permitted for Gale Warning or more-severe warnings issued by the National Weather Service.

In January 2020, PFMC and NOAA implemented regulations that extended the use of streamer lines on nontribal longline vessels to those 26 ft or longer when fishing in federal waters north of lat 36°N (USOFR 2019). This rule also provided an exemption to streamer line use for vessels setting and fishing at night, defined as 1 hr after sunset to 1 hr before sunrise (USOFR 2019).

As a result of these regulations, WCR has asked WCGOP to collect data that may be used to characterize and evaluate the effectiveness of seabird avoidance gear or measures used by longline vessels. Prior to these regulations, some vessels voluntarily used a number of seabird avoidance and mitigation measures, and WCGOP opportunistically collected data regarding these voluntary measures. Here we present data from all vessels, regardless of size and from all years for which WCGOP has collected data.

Figure 11 presents the percentage of hook-and-line gear deployments by year that used specific seabird mitigation for vessels across all fisheries. Noise is often used to scare birds away from setting hooks and includes the use of firecrackers, flash-bangs, whistlers, and other types of loud noises. Figure 12 shows the same data as Figure 11 broken down by fishery.

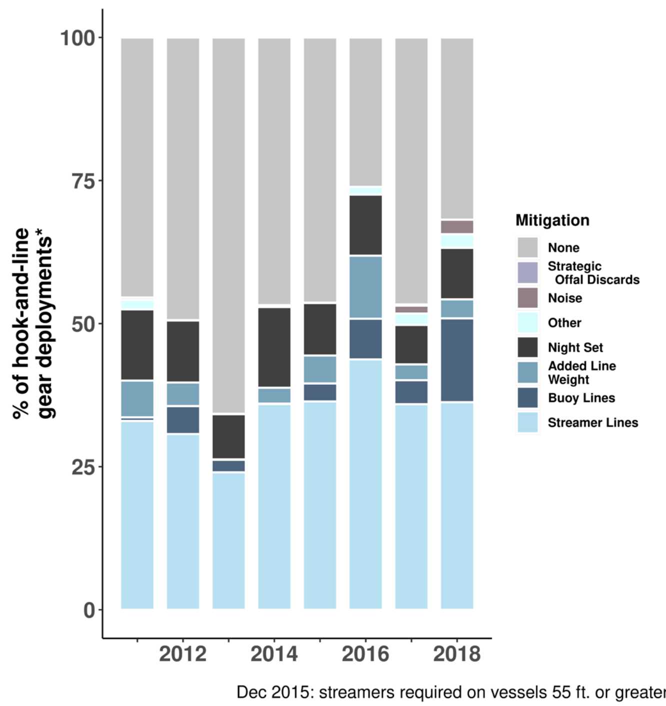

Figure 11. Percentage of observed hauls with seabird mitigation type, by year, 2011–18. More than one type could be used on a single haul. Data on seabird mitigation type were not collected prior to 2009. Only vessels using H&L gears are shown. Vessels over 55 ft in length using H&L gear were required to use streamer lines starting in December 2015.

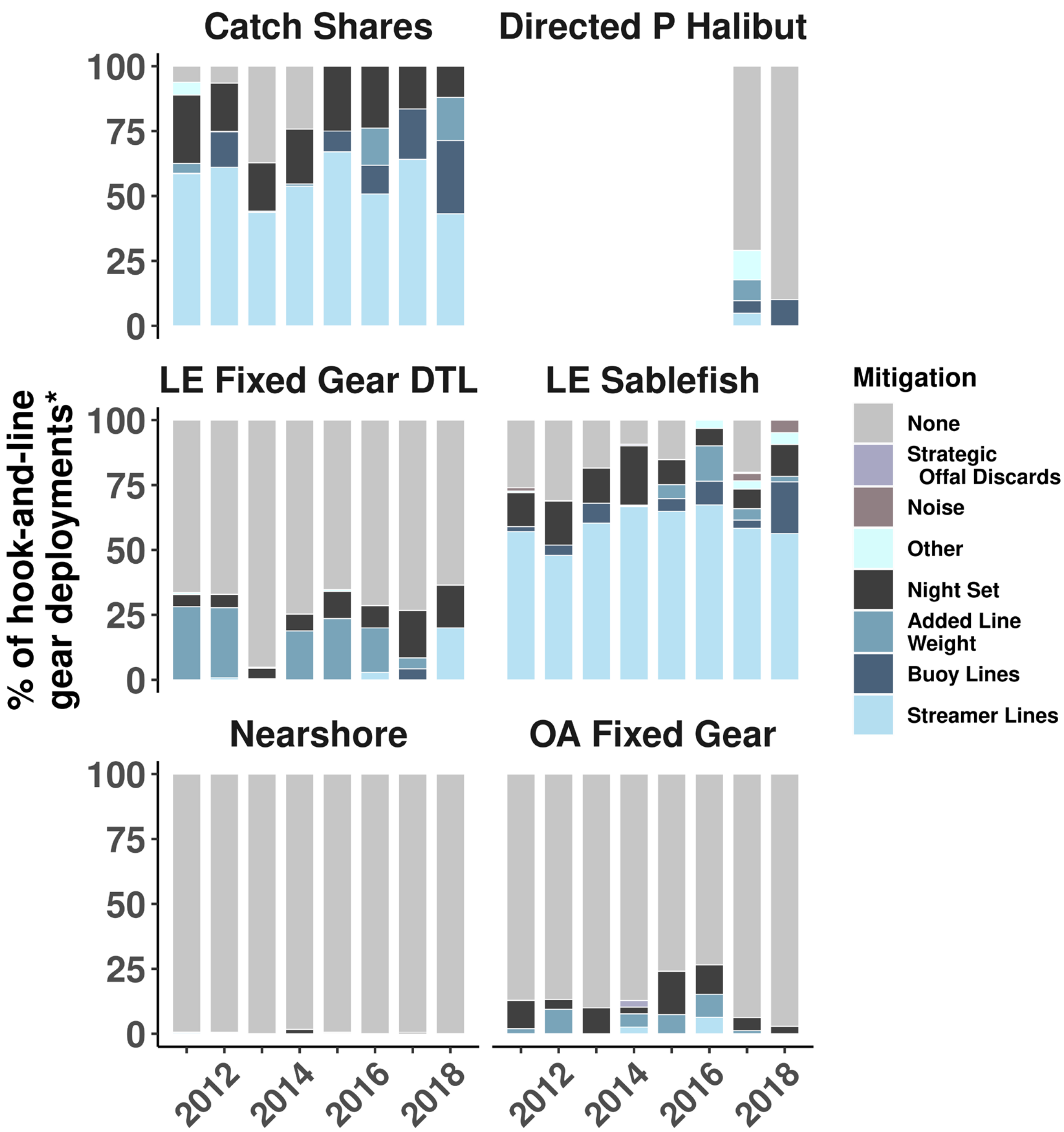

Figure 12. Percentage of observed hauls with seabird mitigation for each fishery, by year, 2011–18. More than one type of mitigation could be used on a single haul. Data on seabird mitigation type were not collected prior to 2009. Only vessels using H&L gears are shown. Vessels over 55 ft in length using H&L gear were required to use streamer lines starting in December 2015.

Seabird Nonlethal Interactions and Sightings

In addition to lethal interactions, both A-SHOP and WCGOP collect information regarding seabird interactions that are not lethal nor are likely to cause injury. Interactions are defined here as any bird that comes into contact with the vessel, gear, catch, or vessel discharge (e.g., offal, discards, vessel trash, etc.; Figures 13 and 14). Sightings of seabirds that do not interact with the vessel in any manner are also recorded. Collection of data on ESA-listed species is a high priority for observers, who are instructed to document all nonlethal interactions and sightings of ESA-listed seabird species. However, because observers are not required to set aside time during every day to record sightings, these observations are opportunistic and rarely collected for non-ESA species. Furthermore, nonlethal and sighting observations reported here are limited in scope to vessel location, which is driven by fishing activity. See Table 2 for the number of recorded sightings for each species for all years combined.

In total, there have been 245 short-tailed albatross nonlethal interactions and sightings recorded by observers in the period 2002–18 (Figure 15, Tables 20 and 21). These short-tailed albatross nonlethal and sightings data update the map presented in Guy et al. (2013), which only included FOS data through 2010. The largest number of observed short-tailed albatross was just south of San Francisco Bay, California; however, significant

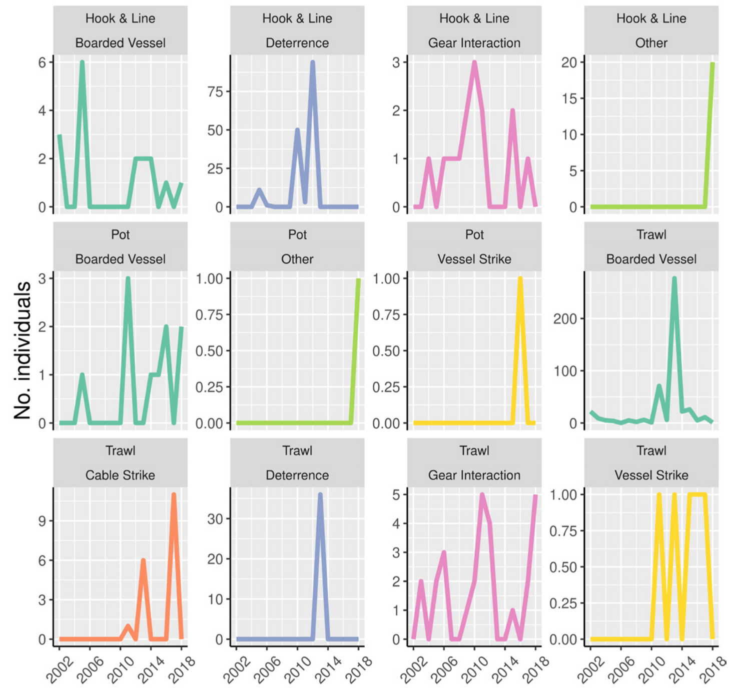

Figure 13. Observed number of nonlethal, nonfeeding seabird interactions by year, gear type, and nonlethal interaction type, 2002–18. Feeding interactions are shown in Figure 14.

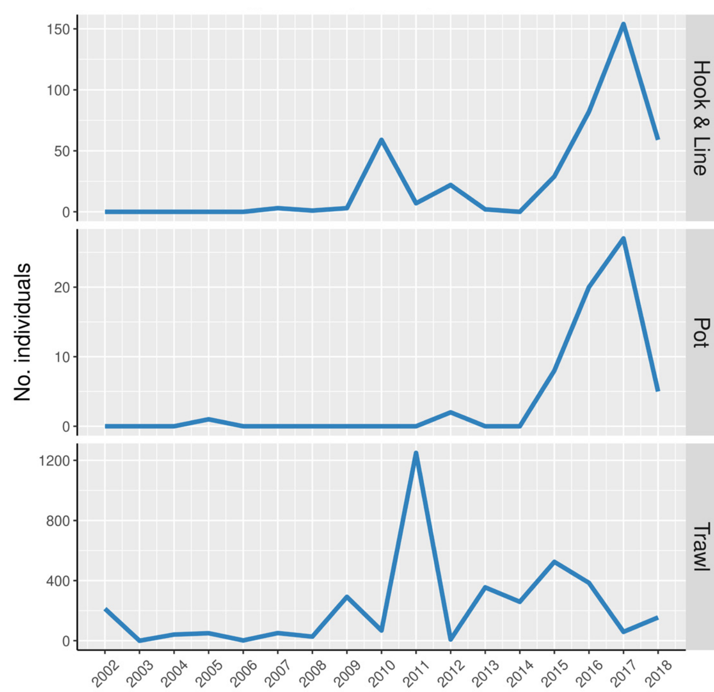

Figure 14. Observed number of seabirds feeding on bait, catch, or discards, by year and gear type, 2002–18.

numbers have occurred off Cape Flattery and Aberdeen, Washington, the mouth of the Columbia River, and Coos Bay, Oregon (Figure 15). The majority of observations appear to be associated with the continental shelf/slope break, consistent with the findings of Guy et al. (2013).

Observers recorded 12 marbled murrelet nonlethal interactions and sightings along the U.S. West Coast during the 2002–18 period (Figure 16, Tables 20 and 21). The largest number of individuals (seven) was observed in northern California. Observations range from south of San Francisco Bay to the central Oregon coast, mainly in the nearshore environment (Figure 16).

Observers recorded five California least tern sightings during the 2002–18 period, all within Pierpoint Bay (Ventura, California; Figure 17, Table 21). No nonlethal interactions of California least tern have been observed (Table 20).

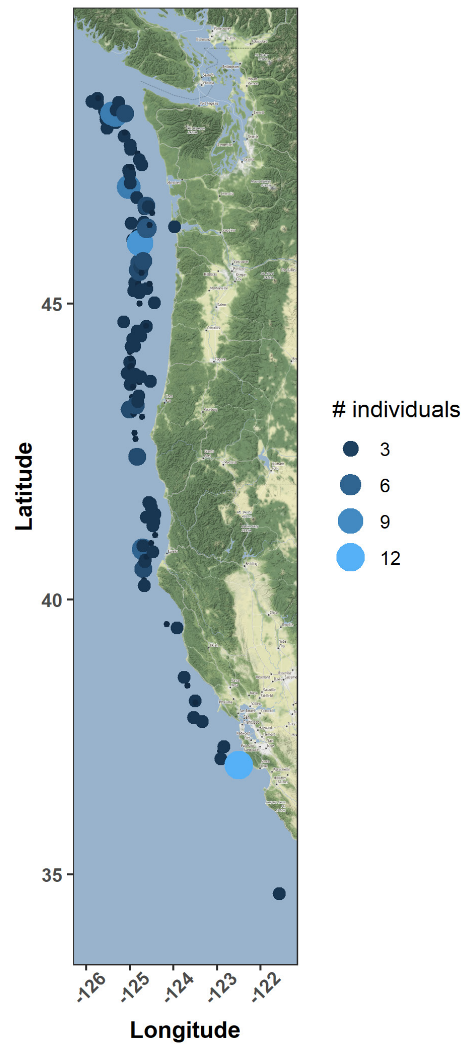

Figure 15. Spatial distribution of observed nonlethal interactions and sightings of STAL from observers on fishing vessels along the U.S. West Coast (WA, OR, CA; 2002–18). Data are not considered to be randomly sampled. Three observations were removed because the sighting position occurred on land.

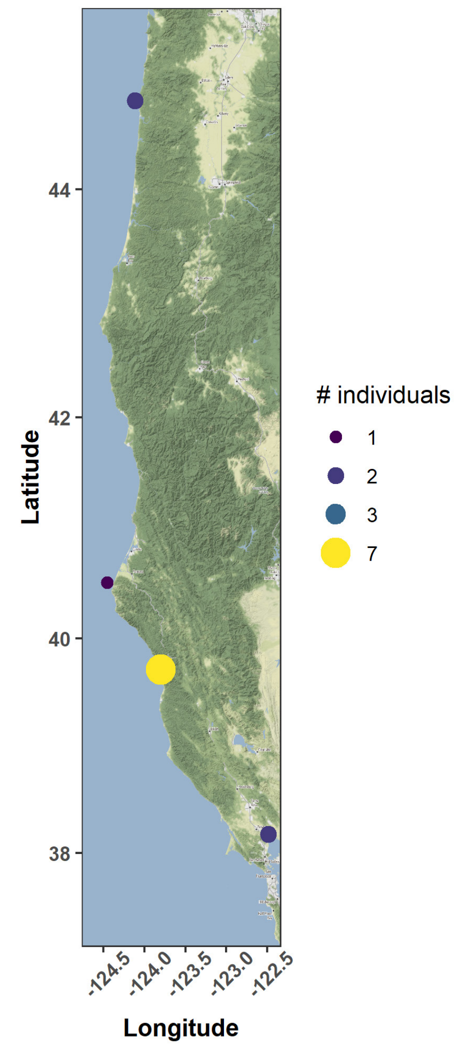

Figure 16. Spatial distribution of observed nonlethal interactions and sightings of marbled murrelets from observers on fishing vessels along the U.S. West Coast (WA, OR, CA; 2002–18). Data are not considered to be randomly sampled.

Table 20. Nonlethal interactions of ESA-listed species recorded by observers on fishing vessels along the U.S. West Coast (WA, OR, CA; 2002–18). Data are not considered to be randomly sampled. Nonlethal interactions of all species (ESA and non-ESA), by fishery, are presented in the Supplemental Tables.

Year	Species	Interaction	Observed number
2002	Marbled murrelet	Boarded Vessel	1
2002	Short-tailed albatross	Feeding on Catch	2
2009	Short-tailed albatross	Feeding on Catch	2
2010	Short-tailed albatross	Feeding on Bait—Floating Free	1
2010	Short-tailed albatross	Feeding on Catch	3
2011	Short-tailed albatross	Feeding on Catch	6
2011	Short-tailed albatross	Feeding on Discarded Catch	3
2012	Short-tailed albatross	Feeding on Catch	7
2013	Short-tailed albatross	Feeding on Catch	4
2014	Short-tailed albatross	Feeding on Catch	4
2015	Short-tailed albatross	Feeding on Catch	2
2015	Short-tailed albatross	Feeding on Discarded Catch	1
2016	Short-tailed albatross	Feeding on Bait—Floating Free	5
2016	Short-tailed albatross	Feeding on Catch	2
2016	Short-tailed albatross	Feeding on Offal	1
2017	Short-tailed albatross	Feeding on Catch	2
2017	Short-tailed albatross	Feeding on Discarded Catch	8
2018	Short-tailed albatross	Feeding on Bait—Floating Free	3
2018	Short-tailed albatross	Feeding on Catch	4
2018	Short-tailed albatross	Feeding on Discarded Catch	3
2018	Short-tailed albatross	Feeding on Offal	6

Table 21. Sightings of ESA-listed species recorded by observers on fishing vessels along the U.S. West Coast (WA, OR, CA; 2002–18). Data are not considered to be randomly sampled. Sightings of all species (ESA and non-ESA), by fishery, are presented in the Supplemental Tables.

Year	Species	Interaction	Observed number
2016	California least tern	Sighting Only	2
2018	California least tern	Sighting Only	3
2012	Marbled murrelet	Sighting Only	4
2017	Marbled murrelet	Sighting Only	7
2002	Short-tailed albatross	Sighting Only	13
2003	Short-tailed albatross	Sighting Only	5
2004	Short-tailed albatross	Sighting Only	4
2005	Short-tailed albatross	Sighting Only	6
2006	Short-tailed albatross	Sighting Only	4
2007	Short-tailed albatross	Sighting Only	3
2008	Short-tailed albatross	Sighting Only	2
2009	Short-tailed albatross	Sighting Only	18
2010	Short-tailed albatross	Sighting Only	12
2011	Short-tailed albatross	Sighting Only	27
2012	Short-tailed albatross	Sighting Only	14
2013	Short-tailed albatross	Sighting Only	11
2015	Short-tailed albatross	Sighting Only	1
2016	Short-tailed albatross	Sighting Only	4
2017	Short-tailed albatross	Sighting Only	11
2018	Short-tailed albatross	Sighting Only	10

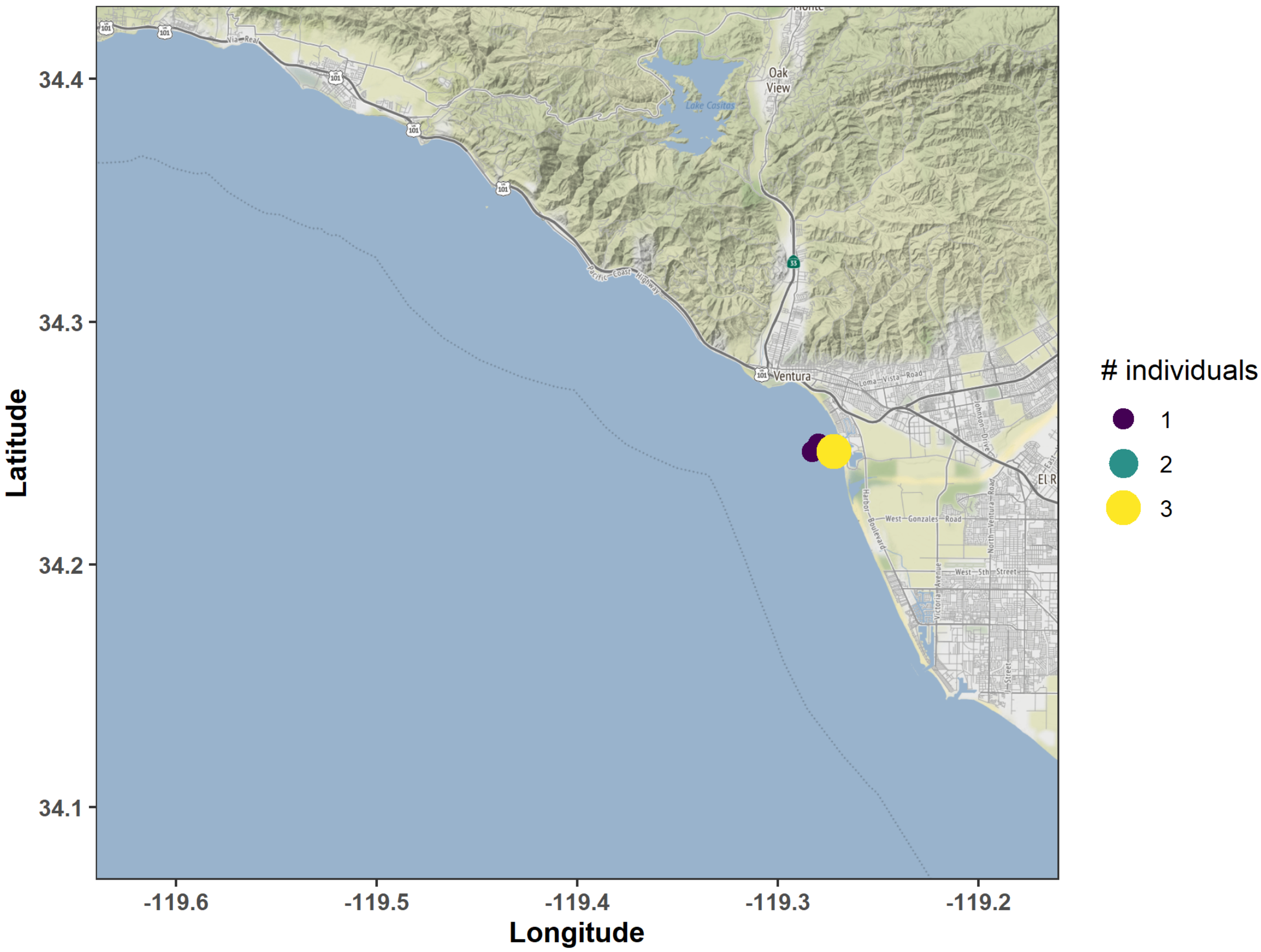

Figure 17. Spatial distribution of observed nonlethal interactions and sightings of California least tern from observers on fishing vessels along the U.S. West Coast (WA, OR, CA; 2002–18). Data are not considered to be randomly sampled.

Methods

Data Sources

Data sources for this analysis include on-board observer data (from WCGOP and A-SHOP), landing receipt data (referred to as fish tickets, obtained from PacFIN), and data generated from vessels carrying EM equipment. Currently only vessels in the IFQ program fishing on an exempted fishing permit (EFP) carry EM equipment (see Somers et al. 2019b for observer and EM coverage rates). The Pacific States Marine Fisheries Commission houses and delivers EM data to FOS. Handling rules for vessels under the current EM EFP require vessel personnel to clearly display any protected species bycatch, including seabirds, to the EM camera system for identification and documentation. WCGOP also places observers on a randomly selected subset of EM vessels for protected species sampling (see Somers et al. 2019b). A list of fisheries, coverage priorities, and data collection methods employed by WCGOP in each observed fishery can be found in the WCGOP manuals (NWFSC 2020b). A-SHOP program information, documentation and data collection methods can be found in the A-SHOP observer manual (NWFSC 2020a). Both WCGOP and A-SHOP observer coverage and effort are reported by fishery and year in Somers et al. (2019b).

WCGOP observers mainly sample the discarded portion of the catch of each haul. Trip-level fish landing receipts (a.k.a. fish tickets) are used to adjust observer estimates of retained catch, to ensure estimates of the retained catch are accurate. This process is described on the WCGOP Data Processing webpage and was conducted prior to the analyses presented in this report.[2]

For data processing purposes, species and species groups were defined based on management (see Table A-1 in Appendix A of Somers et al. 2019b). A complete listing of groundfish species is defined in the Pacific Coast Groundfish Fishery Management Plan (PFMC 2019).

Fish ticket landing receipts are completed by fish buyers in each port for each delivery of fish by a vessel. Fish tickets are trip-aggregated sales receipts for market categories that may represent single or multiple species. Fish tickets are issued to fish buyers by a state agency and must be returned to the agency for processing. Fish ticket and species-composition data are submitted by state agencies to the PacFIN regional database. Annual fish ticket landings data were retrieved from the PacFIN database (April 2020) and subsequently divided into various fisheries of the groundfish fishery, as detailed in Somers et al. (2019b).

For all PacFIN, WCGOP, and A-SHOP data, we maintain confidentiality of persons and businesses, as required by the Magnuson–Stevens Fishery Conservation and Management Act (MSA), most recently reauthorized in 2007. NMFS guidance recommends, and FOS follows, the “rule of three,” according to which: “Information from at least three participants in the fishery must be aggregated/summarized at a temporal and spatial level to protect not only the identity of a person or a business, but also any business information.”

[2] https://www.fisheries.noaa.gov/west-coast/fisheries-observers/west-coast-groundfish-observer-program-data-processing

Maps

We use ten catch classifications to apply the Jenks method to the maps, rather than a continuous variable. This makes it easier to visualize different levels of catch, because it minimizes variance within each class and maximizes variance between classes. Using categorical classifications highlights the patterns better than a continuous gradient when there are many cells with low catch and only a few cells with high catch.

Statistical Software

The statistical software R (R Core Team 2019) was used to produce the analyses, tables, and figures in this report. Specifically, we relied heavily on the R packages:

- `bycatch` (Ward 2017) for modeling and simulation.
- `ggplot2` (Wickham 2016) for plotting figures.
- `loo` (Vehtari et al. 2017, 2019a), as implemented in `bycatch`, for model comparisons.
- `knitr` (Xie 2020) for tables and dynamic reporting.
- `tidyverse` (Wickham et al. 2019) and `dplyr` (Wickham et al. 2020) for data wrangling.

Bycatch Estimation

For some fisheries, 100% observer coverage or electronic monitoring is required on every trip. In these cases, we assume a complete census of seabirds on every haul. Seabird mortality is one of the highest priorities of observers, and crew are required to hold all seabirds up to the camera on EM vessels. However, a small portion of the catch can be unobserved on 100%-coverage vessels, e.g., when hauls are subsampled or if an observer is ill. In these cases, we do simple extrapolations to estimate unobserved seabird mortality (see below). For fisheries with less than 100% monitoring, we use a model-based approach employing Bayesian methods.

Fisheries with less than 100% observer coverage

Fisheries observers monitor and record catch data on commercial fishing vessels by following protocols in the WCGOP manual (NWFSC 2020b). Observer sampling focuses on discarded catch, and supplements existing fish ticket landing receipt data to inform weights of retained catch. Observers generally sample 100% of tows or sets made during a trip. On trawlers, the total weight of discarded catch is estimated, and the discarded catch is then sampled for species composition. The species composition sample could represent either a census or a subsample of all discarded catch. On fixed gear vessels (hook-and-line and pot gears), observers sample total catch (similar to at-sea hake observer sampling methodology) and sample anywhere from 30 to 100% of the catch from each set.

Seabirds are often encountered while the observer is conducting species composition sampling, and thus might not be fully accounted for in the sampled portion of the catch alone. Prior to computing bycatch rates, the number of seabirds in the sample must be expanded to the tow/set level, as explained on the WCGOP Data Processing webpage.

Bycatch for the sampled portion of each fleet must be expanded to the unsampled portion of the fleet in fisheries where there is less than 100% observer monitoring. Historically, we have used ratio estimators to estimate seabird mortality in these fisheries (Jannot et al. 2011). Ratio estimators have been widely used in discard estimation (Stratoudakis et al. 1999, Borges et al. 2005, Walmsley et al. 2007). This method relies heavily on the assumption that bycatch is proportional to some metric or proxy of fishing effort, such as fishery landings (Rochet and Trenkel 2005). Rochet and Trenkel (2005) note that this assumption is often not supported by data and that in some cases, bycatch might vary nonlinearly or even be unrelated to the ratio denominator. Most seabird species are encountered so rarely by these fisheries that it is difficult to assess whether the number of bycatch events is indeed linked to levels of fishing effort. Furthermore, bycatch estimates produced using ratio estimators have been shown to be biased, particularly when observer coverage is low (Carretta and Moore 2014, Martin et al. 2015).

To overcome the limitations of ratio estimators for estimating seabird bycatch, we applied a Bayesian modeling approach. Jannot et al. (2018) examined the differences between estimates calculated with a ratio estimator and those calculated with the Bayesian method. There are significant differences in annual bycatch estimates between the Bayesian approach and the ratio estimator method, as was expected (Carretta and Moore 2014, Martin et al. 2015, Jannot et al. 2018). We did not post-stratify the data, as has been done in previous reports (Jannot et al. 2011). We tested for the impact of dropping post-stratification by comparing annual Bayesian estimates generated with the strata used previously to those generated without stratification. The largest difference between annual estimates calculated with and without stratification was less than 1%. Thus, it is unlikely that removal of the stratification accounts for the large differences between Bayesian and ratio estimates. Here we report the Bayesian estimates generated without post-stratification. In the future, we will incorporate covariates, such as season, into our estimates.

Bayesian estimation

We used Bayesian time-series models to estimate annual means and variability of seabird bycatch for each taxon within each fishery and gear type. These methods have been used with other rare bycatch species, including cetaceans, delphinids, pinnipeds, sea turtles, and sharks (Martin et al. 2015). For each species–fishery–gear type model, there are three parameterization choices to be made: the effort metric (numbers of gear deployments and gear units, mass of landed catch), the type of bycatch rate (constant or time-varying), and the type of bycatch-generating process (Poisson or negative binomial). In this report, we formally compare different effort metrics, time-varying to constant bycatch rates, and bycatch-generating model (Poisson vs. negative binomial). We use methods from the `loo` package as implemented in the `bycatch` package (Ward 2017, Vehtari et al. 2019a) to compare among models within each species–fishery–gear type. Final estimates are presented from the single model that best fits the data.

Modeling bycatch

For each species–fishery–gear type combination, the base model assumed bycatch rate was constant and inferred annual expected mortality, given a specified level of effort, using a simple Poisson process model, where the total number of bycatch events were assumed to follow a Poisson distribution,

$$n_{take,y} \sim (\lambda_y = \theta \times E_y),$$

where:

$n_{take,y}$ = number of observed bycatch events (or take events) in year y,
λ_y = mean expected bycatch,
θ = estimated bycatch rate, and
E_y = effort in year y.

The estimated bycatch rate θ is assumed constant through time, but the quantity $\theta \times E_y$ includes uncertainty, as θ is estimated. Thus, a time series of the mean bycatch can be generated for a given species, with a given metric of effort. All uncertainty in the time series originates from fluctuating levels of effort through time (percent observer coverage only affects the expansion). We used a Bayesian model (Martin et al. 2015) to generate mean and 95% CIs of the bycatch rate parameter, θ, as well as for the expected bycatch, $\theta \times E_y$.

In this report, we built upon the simplified model above with the goal of finding the model that most accurately estimates bycatch and variance. To do that, we compared models to: a) find the most suitable effort metric, b) test the assumption that θ is constant through time, and c) compare distributions (Poisson to negative binomial). For each species–fishery–gear type, there are a total of 12 possible models (three effort metrics, two rates, two distributions). To compare among these models, we used two model diagnostic tools (`Pareto-K` and `p-LOO`) and a model comparison method (`LOOIC`) from the `loo` package (Vehtari et al. 2019a) as implemented in the `bycatch` package (Ward 2017).

The `loo` package (Vehtari et al. 2019a) implements leave-one-out (LOO) sampling, a form of cross-validation, which tests the efficacy of the model based on how well it approximates new data. LOO is based on Pareto smoothed importance sampling (PSIS). Importance sampling is typically used when multiple distributions may be used, or when the density of the distribution is only partially known.

Before comparing among models, each model must be tested for efficacy using the `Pareto-K` values. Theoretically, the PSIS should converge to a mean and variance for the distribution; however, due to the use of random variables, convergence does not always emerge. The `loo` package generates a `Pareto-K` value that reflects its convergence properties. A "low" `Pareto-K` value (<0.5) indicates that both the mean and variance converge, reflecting an effective model. A "slightly high" `Pareto-K` value ($0.5 \leq K < 1$) indicates a model whose mean converges, but variance either does not converge at all, or converges slowly. Finally, a "high" `Pareto-K` value ($1 < K$) indicates that neither the mean nor the variance converges. These values are simple heuristics to be used as guidelines, rather than hard rules (Vehtari et al. 2019b).

In addition to `Pareto-K` values, LOO can be used to test for overparameterization by generating a `p-LOO` value which is compared to the number of parameters used in the model. The parameters for the model include all the incorporated covariates, as well as time, effort, and distribution. All models tested here have no covariates, and thus have three parameters (time, effort, distribution). A `p-LOO` less than the number of parameters denotes an appropriately parameterized model.

Once a model is considered suitable, the optimal model can be chosen by comparing among LOOICs, or "leave-one-out information criterions." A LOOIC is based on an expected log predictive density (ELPD). Generally, the preferred model is the model with the lowest LOOIC.

The 12 models within a species–fishery–gear type were tested in the following order, and excluded if any of the following cases were met:

1. `Pareto-K` > 0.7, as suggested by Vehtari et al. (2019b).
2. `p-LOO` > 3 (the number of parameters).
3. LOOIC is not the minimum.

In some cases, all 12 models failed both the `Pareto-K` and `p-LOO` tests. To reduce the model complexity in these cases, we reverted to a constant bycatch rate and Poisson distribution (see above), then compared among effort metrics and chose the single model that minimized all three model diagnostics, even if those diagnostics were larger than recommended.

Expanding bycatch to unobserved portion of fleet

Because observer coverage is less than 100% in some fleets, and variable through time, we need to expand the estimated bycatch, $\theta \times E_y$, to the fleetwide level. One approach for expansion would be to divide $\theta \times E_y$ by the percent observer coverage; however, this ignores uncertainty in the expansion. We accounted for uncertainty in the expansion by treating the observer coverage and estimated bycatch ($\theta \times E_y$) as known and sampling from the distribution of total bycatch in proportion to the binomial density function. This process was repeated for each Markov Chain Monte Carlo (MCMC) draw, to propagate uncertainty in the estimates through the uncertainty in the expansion. Details on the implementation of this in R can be found in the `bycatch` package (Ward 2017). Fleetwide bycatch of each seabird taxon was estimated for each fishery and gear type using observer coverage data (Somers et al. 2019b).

One limitation of this method is that the time series must be complete (i.e., no gaps). The OA California halibut fishery was observed from 2003–05 and 2007–present, but not in 2006. To create a complete series (2003–present), we used the average across 2004–08 to fill in the missing 2006 data. Averaging across years was only employed to create a complete series; therefore, we do not report bycatch estimates for 2006 for the OA California halibut fishery.

Fisheries with 100% observer coverage

There are two fisheries with 100% observer coverage: the at-sea hake fishery and the shoreside IFQ fishery. For these fisheries, we assume a complete census of seabirds on every haul, since seabird mortality is one of the highest priorities of observers and crew are required to hold all seabirds up to the camera on EM vessels. However, a portion of the catch can be unobserved on 100% coverage vessels—e.g., when hauls are subsampled or if an observer is ill. In these cases, we do simple extrapolations to estimate unobserved seabird mortality.

At-sea hake fishery

The at-sea hake fishery (observed by A-SHOP) and the catch share, or IFQ, fishery (observed by WCGOP) both require 100% observer coverage. Currently in the catch share fishery, vessels that participate in the EM program can forgo 100% observer coverage provided that:

- They hold an exempted fishing permit for the EM program.
- Electronic monitoring equipment is installed, used, and working properly on every trip.
- They take observers for scientific data collection on trips when selected to do so by FOS.

A-SHOP observers monitor for seabirds in two distinct ways. First, if a seabird was caught and is present in the observer's species composition sample, the appropriate information (including weight, length, etc.) is documented. Secondly, observers monitor the dumping of catch from the net into the sorting tank for about 50–70% of the hauls. This is done to detect the presence of marine mammals; however, observers would also collect any seabirds at this time if any were observed, e.g., caught in the warps, cables, or wings of the net. These observations are considered opportunistic and are not used to extrapolate seabird mortality to the unsampled portion of the catch. Observers also record information on nonlethal interactions seen between fishing operations and seabirds, and document sightings of ESA-listed species, as time allows.

Bycatch data for seabirds are primarily recorded during species composition sampling. Seabirds are small enough to make it below deck, where the observer samples the catch, and are recorded only if they happen to be included in the observer's random species composition sample of a particular tow. Any bycatch of seabirds recorded in a species composition sample must be expanded to the haul level. Often, this results in the observation of one seabird expanding to two seabirds, depending on the observed sample size for that haul. However, since every vessel is observed and almost 100% of the fleet's tows are sampled, the bycatch expansion to the entire at-sea fishery is quite small.

To estimate total seabird bycatch in the at-sea hake fishery, all of the sampled tows were used in our analysis after the bycatch estimate of seabirds was expanded within each sampled tow. In rare instances, for example if a tow goes unsampled, the estimate is then used to expand to the unobserved portion of the fleet. This method for calculating seabird bycatch is the same as the method used to calculate fish bycatch in the at-sea hake fishery.

For each seabird species, the total number of takes during each tow was calculated using the following formula:

$$Y_t = y_t \times \frac{W_t}{w_t}$$

where:

Y_t = total number of takes in tow t,
y_t = number of observed takes in the species composition of tow t,
W_t = weight of the total catch in tow t, and
w_t = weight of the sampled catch in tow t.

The total number of takes of each seabird species in the at-sea hake fleet was then calculated using the following formula:

$$B = \sum_t Y_t \times \left(\frac{C_{total}}{c_{obs}}\right)$$

where:

B = total estimated bycatch for the species,
C_{total} = total catch from all tows in the at-sea hake sector,
c_{obs} = catch from the observed tows in the at-sea hake sector, and
w_t = weight of the sampled catch in tow t.

Seabird bycatch data do not contain the necessary replicates for calculating within-tow variation. The only source of uncertainty that could have been evaluated for fleetwide seabird bycatch estimates was that associated with the variance between tows. Since nearly 100% of tows were sampled, this variation was quite small and not useful for estimating uncertainty.

Seabird cable strikes on at-sea catcher–processors

On at-sea hake catcher–processor vessels, some incidental seabird mortality could occur when birds collide with the trawl door warp wires or trawl net data cables during gear deployment or fishing. In the past, these interactions went unobserved, as fisheries observers do not normally monitor the setting or fishing of the gear. However, from 2016–19, we trained fisheries observers to sample seabird cable strikes during daylight trawling activities twice per day, at randomly selected 15-minute intervals. We used a modified version of Melvin et al.'s (2011) data collection protocols. Fisheries observers recorded the species and number of birds colliding with cables, the date and time, the type of strike (hard or soft), weather conditions, the configuration of cables, and characteristics of the offal discharge—the main attraction for seabirds. Hard strikes are defined as those that result in the bird changing course, falling into the water, or being dragged underwater, whereas soft strikes are defined as those that result from the bird being lightly touched by cables and/or moving away from them in a controlled manner. Differentiating hard strikes from soft is important, as hard strikes are more likely to result in mortality (Sullivan et al. 2006a, 2006b, Melvin et al. 2011). Additional fishing activity information was recorded by observers, including net deployment/retrieval location, date, and time; these were used to expand observed times to total minutes of daylight trawling activity for the entire at-sea catcher–processor fleet. Observations of cable strikes by species recorded during this special project are presented in Supplemental Table 28.

We used a Bayesian time series model (see above), with fishing season (spring = May–June, fall = August–November) as a covariate and the total hours of trawling activity as the metric of effort, to estimate the total number of hard strikes by species, season, and year. Preliminary data analyses suggested that season might play an important role in determining seabird risk for cable strikes (data not shown). We took the average number of hard strikes across seasons and years, with mortality rate applied (Table 22) as an estimate of annual mortalities due to cable strikes. This number was then added to the estimated mortality (see above) for each year for the catcher–processor fleet only.

Cable strike mortality rate calculation

Not all hard strikes will result in mortality; thus, a species-specific mortality rate must be applied to the total number of cable strikes to obtain estimates of a hard cable-strike mortality (Table 22).

In addition to fisheries observer cable-strike data collection (above; see also Supplemental Table 28), during 2019, NWFSC collaborated with Oregon Sea Grant (OSG) and the at-sea hake industry to place dedicated seabird monitors on at-sea hake catcher–processor vessels to conduct a more focused study of seabird interactions with cables on these midwater trawl vessels (A. Gladics, Oregon Sea Grant, personal communication). The at-sea hake fleet operates from 15 May–31 December from the U.S–Canada border to the Oregon–California border. There are distinct spring (May–June) and fall (August–November) fishing seasons. Methods were modified from Melvin et al. (2011) and similar to the fisheries observer cable-strike data collection (described above; Gladics, personal communication). One major difference was that seabird monitors spent more time watching cables for strike interactions, observing the fate of struck birds, and determining the likely outcome (e.g., no harm, injured, dead) of each cable strike—data that fisheries observers could not obtain because of time constraints and other duties. Thus, the OSG seabird monitors were able to develop species-specific mortality rates for cable strikes on these vessels (Table 22). We applied these mortality rates to our Bayesian estimates of hard strikes and then added this number to the observed mortalities for each species in each year to obtain final mortality estimates for this fleet.

Table 22. Species-specific mortality rates due to cable strikes, as determined by OSG seabird monitors on at-sea hake catcher–processors during the 2019 spring and fall fishing seasons (Gladics, personal communication).

Species	Mortality rate
Northern fulmar	0.0235
Shearwaters*	0.1505
Black-footed albatross	0.0100
Gull, unidentified	0.0450
Pink-footed shearwater	0.1000
Leach's storm-petrel	1.0000

* Sooty and short-tailed, combined.

Shore-based IFQ fisheries

Fleetwide seabird bycatch estimates for the shore-based IFQ fisheries were derived from WCGOP observer data and fish ticket landings data. Fish tickets associated with the IFQ fishery were defined by analysts through an extensive quality control and review process of all available data sources, including those utilized for in-season management (see Appendix B of Somers et al. 2019b).

IFQ bottom trawl vessels can hold a California halibut bottom trawl permit and participate in the state-permitted California halibut fishery. Limited entry California halibut tows can occur on the same trip as tows targeting IFQ groundfish, and were identified at the tow level based on the use of bottom trawl gear and the following criteria: 1) the target was California halibut and more than 150 lb of California halibut were landed, or 2) the target was nearshore mix, sand sole, or other flatfish, and the tow took place in less than 30 fathoms and south of lat 40°10′N.

All IFQ bottom trawl tows that met at least one of the above requirements were analyzed using methods for IFQ discard estimation to reflect the sampling protocol performed by observers on the boat. Tow targets are typically determined by the vessel captain. Since 2013, no limited entry California halibut tows have occurred.

Since 2011, all (100%) IFQ trips are required to carry an observer or EM equipment. Therefore, observed counts of seabird bycatch in these fisheries represent a near-complete census. However, on rare occasions, sets (or portions thereof) are unsampled. The unsampled portion of catch is typically less than 1% in any given year. We used ratio estimators to apportion any unsampled bycatch to specific species, based on observed numbers of individuals in the sampled catch. In most cases, this adds only a small amount (less than a whole bird) to our estimates of seabird bycatch. In the spirit of transparency, we provide the methods below for expanding this very small amount.

Infrequently, entire hauls, including species that would have normally been retained, are discarded at sea, either because of gear malfunctions (e.g., net rips before landed) or operational considerations (e.g., deliberate release of catch from net before landing because of safety or other concerns). In these instances, the observer records a visual estimate of unsorted catch weight, including both discarded and retained species. Very infrequently, haul data fail quality control measures. In all of these cases, bycatch was estimated based on retained weight from fish tickets. To obtain the estimated number of discarded individuals of a species (B) when the entire haul or set was unsampled, the unsampled weight was multiplied by the ratio of the bycatch number of individuals of the species divided by either a) the weight of all species (discarded + would-have-been-retained) discarded at sea, or b) the retained weight of all species in all sampled hauls, depending on whether the haul was unsampled because of complete discard at sea (a) or failed data (b):

$$\hat{B} = \sum_p x_p \times \frac{\sum_f b_f}{\sum_f x_f}$$

where:

$\hat{B}$ = estimated number of unsampled individuals of a given species,
p = unsampled haul,
x_p = weight of the unsampled haul discarded at sea,
f = sampled haul,
x_f = weight of all retained species from fish tickets on sampled hauls, and
b = sampled number of individuals of a given species.

We used discard weight as the denominator in the ratio because we only have an estimated weight of unsampled hauls; counts of individuals are not available for unsampled hauls.

For partially unsampled hauls, observers are instructed to sample such that species in the sample are not also included in the unsampled portion of the catch, to avoid double-counting. To obtain the estimated number of bycatch individuals (B) included in partially sampled hauls, the unsampled discard weight (visually estimated) was multiplied by the ratio of the sampled number of individuals of the species divided by the sampled weight of all species.

The estimated number of unsampled individuals of a particular species was then added to the sampled number of individuals of that species to obtain the total bycatch estimate.

References

Ainley, D., L. Spear, C. Tynan, J. Barth, S. Pierce, R. Glenn Ford, and T. Cowles. 2005. Physical and biological variables affecting seabird distributions during the upwelling season of the northern California Current. Deep Sea Research Part II: Topical Studies in Oceanography 52:123–143.

Anderson, O. R. J., C. J. Small, J. P. Croxall, E. K. Dunn, B. J. Sullivan, O. Yates, and A. Black. 2011. Global seabird bycatch in longline fisheries. Endangered Species Research 14(2):91–106.

Baker, G. B., M. C. Double, R. Gales, G. N. Tuck, C. L. Abbott, P. G. Ryan, S. L. Petersen, C. J. R. Robertson, and R. Alderman. 2007. A global assessment of the impact of fisheries-related mortality on shy and white-capped albatrosses: Conservation implications. Biological Conservation 137:319–333.

Bakun, A., D. McLain, and F. Mayo. 1974. The mean annual cycle of coastal upwelling off western North America as observed from surface measurements. Fishery Bulletin 72:843–844.

Barth, J., S. Pierce, and R. Smith. 2000. A separating coastal upwelling jet at Cape Blanco, Oregon and its connection to the California Current System. Deep Sea Research Part II: Topical Studies in Oceanography 47:783–810.

Bartle, J. A. 1991. Incidental capture of seabirds in the New Zealand subantarctic squid trawl fishery, 1990. Bird Conservation International 1:351–359.

Borges, L., A. R. Zuur, E. Rogan, and R. Officer. 2005. Choosing the best sampling unit and auxiliary variable for discards estimations. Fisheries Research 75:29–39.

Briggs, K., and E. Chu. 1986. Sooty shearwaters off California: Distribution, abundance and habitat use. Condor 88:355–364.

Butchart, S. H., A. J. Stattersfield, L. A. Bennun, S. M. Shutes, H. R. Akcakaya, J. E. Baillie, S. N. Stuart, C. Hilton-Taylor, and G.M. Mace. 2004. Measuring global trends in the status of biodiversity: Red List indices for birds. PLoS Biology 2:e383.

Carretta, J. V., and J. E. Moore. 2014. Recommendations for pooling annual bycatch estimates when events are rare. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-528.

Croxall, J. P., S. H. M. Butchart, B. Lascelles, A. J. Stattersfield, B. Sullivan, A. Symes, and P. Taylor. 2012. Seabird conservation status, threats and priority actions: A global assessment. Bird Conservation International 22(1):1–34.

Endangered Species Act of 1973. U.S. Code, volume 16, section 1532(19).

Favero, M., G. Blanco, G. García, S. Copello, J. P. Seco Pon, E. Frere, F. Quintana, P. Yorio, F. Rabuffetti, G. Cañete, and P. Gandini. 2011. Seabird mortality associated with ice trawlers in the Patagonian shelf: Effect of discards on the occurrence of interactions with fishing gear. Animal Conservation 14(2):131–139.

Ford, R., D. Ainley, J. Casey, C. Keiper, L. Spear, and L. Ballance. 2004. The biogeographic patterns of seabirds in the central portion of the California Current. Marine Ornithology 32:77–96.

González-Zevallos, D., P. Yorio, and G. Caille. 2007. Seabird mortality at trawler warp cables and a proposed mitigation measure: A case of study in Golfo San Jorge, Patagonia, Argentina. Biological Conservation 136(1):108–116.

Guy, T. J., S. L. Jennings, R. M. Suryan, E. F. Melvin, M. A. Bellman, L. T. Ballance, B. A. Blackie, D. A. Croll, T. Deguchi, T. O. Geernaert, R. W. Henry, M. Hester, K. D. Hyrenbach, J. Jahncke, M. A. Kappes, K. Ozaki, J. Roletto, F. Sato, W. J. Sydeman, and J. E. Zamon. 2013. Overlap of North Pacific albatrosses with the U.S. West Coast groundfish and shrimp fisheries. Fisheries Research 147:222–234.

Hyrenbach, K., P. Fernandez, and D. J. Anderson. 2002. Oceanographic habitats of two sympatiric North Pacific albatross. Marine Ecology Progress Series 233:283–301.

IUCN (International Union for Conservation of Nature). 2020. The IUCN Red List of Threatened Species, version 2020-1. Available: www.iucnredlist.org (April 2020).

Jannot, J. E., K. A. Somers, V. Tuttle, J. McVeigh, and T. P. Good. 2018. Seabird Mortality in U.S. West Coast Groundfish Fisheries, 2002–16. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-146. DOI: 10.25923/qeyc-0r73.

Jannot, J., E. Heery, M. A. Bellman, and J. Majewski. 2011. Estimated bycatch of marine mammals, seabirds, and sea turtles in the U.S. West Coast commercial groundfish fishery, 2002-2009. Northwest Fisheries Science Center, Seattle.

Lascelles, B., J. Rice, M. Sato, M. Tarzia, and R.M. Wanless. 2016. Chapter 38. Seabirds. *In* L. Innis, A. Simcock, A. Y. Ajawin, A. C. Alcala, P. Bernal, H. P. Calumpong, P. E. Araghi, S. O. Green, P. Harris, O. K. Kamara, K. Kohata, E. Marschoff, G. Martin, B. P. Ferreira, C. Park, R. A. Payet, J. Rice, A. Rosenberg, R. Ruwa, J. T. Tuhumwire, S. Van Gaever, J. Wang, and J. M. Węsławski, editors. The First Global Integrated Marine Assessment World Ocean Assessment I. United Nations General Assembly. United Nations, New York. Available: www.un.org/Depts/los/global_reporting/WOA_RegProcess.htm (April 2020).

Lewison, R. L., and L. B. Crowder. 2003. Estimating fishery bycatch and effects on a vulnerable seabird population. Ecological Applications 13:743–753.

Magnuson–Stevens Fishery Conservation and Management Act of 1976. Magnuson–Stevens Fishery Conservation and Management Reauthorizaton Act of 2006. U.S. Code, volume 16, section 1802(23).

Maree, B. A., R. M. Wanless, T. P. Fairweather, B. J. Sullivan, and O. Yates. 2014. Significant reductions in mortality of threatened seabirds in a South African trawl fishery. Animal Conservation 17(6):520–529.

Martin, S. L., S. M. Stohs, and J. E. Moore. 2015. Bayesian infrerence and assessment for rare-event bycatch in marine fisheries: A drift gillnet fishery case study. Ecological Applications 25:416–429.

Melvin, E. F., K. S. Dietrich, S. Fitzgerald, and T. Cardoso. 2011. Reducing seabird strikes with trawl cables in the pollock catcher–processor fleet in the eastern Bering Sea. Polar Biology 34:215–226.

Naughton, M. B., D. J. Pitkin, R. W. Lowe, K. J. So, and C. S. Strong. 2007. Catalog of Oregon seabird colonies. U.S. Fish and Wildlife Service, Biological Technical Publication BTP-R1009-2007. Available: www.fws.gov/uploadedFiles/Catalog_of_Oregon_Seabird_Colonies_1-TOC.pdf (April 2020).

NWFSC (Northwest Fisheries Science Center). 2020a. At-Sea Hake Observer Program, 2020 Sampling Manual. Northwest Fisheries Science Center, Seattle. Available: archive.fisheries.noaa.gov/nwfsc/research/divisions/fram/observation/data_collection/manuals/A-SHOP%20Manual%202020_508%20compliant.pdf (April 2020).

NWFSC (Northwest Fisheries Science Center). 2020b. West Coast Groundfish Observer Program 2020 Training Manual. Northwest Fisheries Science Center, Seattle. Available: repository.library.noaa.gov/view/noaa/25519 (April 2020).

Parker G. C., P. Brickle, S. Crofts, J. Pompert, and A. C. Wolfaardt. 2013. Research into undetected seabird mortality in a demersal trawl fishery. Fifth Meeting of the Seabird Bycatch Working Group, 1–3 May 2013. Agreement on the Conservation of Albatrosses and Petrels, La Rochelle, France. Available: www.researchgate.net/profile/Graham-Parker/publication/274638191_Research_into_undetected_seabird_mortality_in_a_demersal_trawl_fishery/links/5524428f0cf2b123c5173926/Research-into-undetected-seabird-mortality-in-a-demersal-trawl-fishery.pdf (April 2020).

PFMC (Pacific Fishery Management Council). 2019. Pacific Groundfish Fishery Management Plan. Pacific Fishery Management Council, Portland, Oregon. Available: www.pcouncil.org/documents/2016/08/pacific-coast-groundfish-fishery-management-plan.pdf (April 2020).

R Core Team. 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available: www.r-project.org (April 2020).

Rochet, M. J., and V. M. Trenkel. 2005. Factors for the variability of discards: Assumptions and field evidence. Canadian Journal of Fisheries and Aquatic Sciences 62:224–235.

Somers, K. A., J. E. Jannot, K. Richerson, V. Tuttle, and J. McVeigh. 2019a. Fisheries Observation Science Program Coverage Rates, 2002–18. U.S. Department of Commerce, NOAA Data Report NMFS-NWFSC-DR-2019-01. DOI: 10.25923/kbnn-8373.

Somers, K. A., J. E. Jannot, V. Tuttle, N. B. Riley, and J. T. McVeigh. 2019b. Estimated Discard and Catch of Groundfish Species in the 2017 U.S. West Coast Fisheries. U.S. Deptartment of Commerce, NOAA Technical Memorandum NMFS-NWFSC-150. DOI: 10.25923/kr5q-je83.

Stratoudakis, Y., R. Fryer, R. Cook, and G. Pierce. 1999. Fish discarded from Scottish demersal vessels: Estimators of total discards and annual estimates for targeted gadoids. ICES Journal of Marine Science: Journal du Conseil 56:592.

Sullivan, B. J., P. Brickle, T. A. Reid, D. G. Bone, and D. A. J. Middleton. 2006a. Mitigation of seabird mortality on factory trawlers: Trials of three devices to reduce warp cable strikes. Polar Biology 29:745–753.

Sullivan, B. J., T. A. Reid, and L. Bugoni. 2006b. Seabird mortality on factory trawlers in the Falkland Islands and beyond. Biological Conservation 131:495–504.

Tamini, L. L., L. N. Chavez, M. E. Góngora, O. Yates, F. L. Rabuffetti, and B. Sullivan. 2015. Estimating mortality of black-browed albatross (*Thalassarche melanophris*, Temminck, 1828) and other seabirds in the Argentinean factory trawl fleet and the use of bird-scaring lines as a mitigation measure. Polar Biology 38(11):1867–1879.

Tyler, W., K. Briggs, D. Lewis, and R. Ford. 1993. Seabird distribution and abundance in relation to oceanographic processes in the California Current System. Pages 48-60 *in* K. Vermeer, K. T. Briggs, K. H. Morgan, and D. Siegel-Causey, editors. The status, ecology, and conservation of marine birds in the North Pacific. Canadian Wildlife Service Special Publication, Ottawa.

USFWS (U.S. Fish and Wildlife Service). 2005. Regional Seabird Conservation Plan, Pacific Region. U.S. Fish and Wildlife Service, Portland, Oregon.

USFWS (U.S. Fish and Wildlife Service). 2008. Birds of Conservation Concern 2008. U.S. Fish and Wildlife Service, Arlington, Virginia.

USOFR (U.S. Office of the Federal Register). 2001. 50 CFR Part 660: Fisheries off West Coast States and in the Western Pacific; Pacific Coast Groundfish Fishery; Groundfish Observer Program, final rule (RIN 0648-AN27). Federal Register 66:79(24 April 2001):20609–20614.

USOFR (U.S. Office of the Federal Register). 2015. 50 CFR Part 660: Fisheries Off West Coast States; Pacific Coast Groundfish Fishery; Seabird Avoidance Measures (RIN 0648-BD92). Federal Register 80:222(18 November 2015):71975–71981.

USOFR (U.S. Office of the Federal Register). 2019. 50 CFR Part 660: Magnuson-Stevens Act Provisions; Fisheries Off West Coast States; Pacific Coast Groundfish Fishery; Seabird Bycatch Avoidance Measures (RIN 0648-BI99). Federal Register 84:238(11 December 2019):67674–67680.

Vehtari, A., J. Gabry, M. Magnusson, Y. Yao, and A. Gelman. 2019a. `loo`: Efficient leave-one-out cross-validation and WAIC for Bayesian models. R package version 2.2.0. Available: mc-stan.org/loo (April 2020).

Vehtari, A., D. Simpson, A. Gelman, Y. Yao, and J. Gabry. 2019b. Pareto Smoothed Importance Sampling. arXiv:1507.02646.

Vehtari A., Gelman A., Gabry J. 2017. Practical Bayesian model evaluation using leave-one-out cross-validation and WAIC. Statistics and Computing 27:1413–1432. DOI: 10.1007/s11222-016-9696-4.

Walmsley, S., R. Leslie, and W. Sauer. 2007. Bycatch and discarding in the South African demersal trawl fishery. Fisheries Research 86:15–30.

Ward, E. J. 2017. `bycatch`: Using Bayesian generalized linear models for estimating bycatch rates and generating fleet-level expansions. R package version 1.0. Available: zenodo.org/record/569038#.YD_GYZNKhTY (April 2020).

Watkins, B. P., S. L. Petersen, and P. G. Ryan. 2008. Interactions between seabirds and deep-water hake trawl gear: An assessment of impacts in South African waters. Animal Conservation 11(4):247–254.

Weimerskirch, H., N. Brothers, and P. Jouventin. 1997. Population dynamics of wandering albatross *Diomedea exulans* and Amsterdam albatross *D. amsterdamensis* in the Indian Ocean and their relationships with long-line fisheries: Conservation implications. Biological Conservation 79(2–3):257–270.

Weimerskirch, H., D. Capdeville, and G. Duhamel. 2000. Factors affecting the number and mortality of seabirds attending trawlers and long-liners in the Kerguelen area. Polar Biology 23(4):236–249.

Wickham, H. 2016. `ggplot2`: Elegant Graphics for Data Analysis. Springer–Verlag, New York.

Wickham, H., M. Averick, J. Bryan, W. Chang, L. D. McGowan, R. François, G. Grolemund, A. Hayes, L. Henry, J. Hester, M. Kuhn, T. L. Pedersen, E. Miller, S. M. Bache, K. Müller, J. Ooms, D. Robinson, D. P. Seidel, V. Spinu, K. Takahashi, D. Vaughan, C. Wilke, K. Woo, and H. Yutani. 2019. Welcome to the Tidyverse. Journal of Open Source Software 4(43):1686. DOI: 10.21105/joss.01686.

Wickham, H., R. Francois, L. Henry, and K. Muller. 2020. `dplyr`: A Grammar of Data Manipulation. R package version 0.8.4. Available: cran.r-project.org/web/packages/dplyr/index.html (April 2020).

Williams, R., and D. Capdeville. 1996. Seabird interactions with trawl and longline fisheries for *Dissostichus eleginoides* and *Champsocephalus gunnari.* CCAMLR Science 3:93–96.

Xie, Yihui. 2020. `knitr`: A General-Purpose Package for Dynamic Report Generation in R. R package version 1.28.

Appendix A: Fishery Descriptions

Table A-1. A description of permits, gears used, target groups, vessel length range, fishing depth range, and management of fisheries, sectors, and subsectors in federally managed U.S. West Coast groundfish catch share fisheries. For brevity, management descriptors are generalized for the given time period and are not meant to be complete or comprehensive. LE = limited entry, BT = bottom trawl, H&L = hook-and-line, IFQ = individual fishing quota, EM = electronic monitoring, MW = midwater, P. = Pacific, MSCV = mothership catcher vessel, CP = catcher–processor.

Sector	Subsector	Permit	Gear	Target	Vessel length (m)	Depth (m)	Management
LE trawl	LE trawl	LE with trawl endorsement[a]	BT H&L pot	Groundfish[b]	15–40	10–1,600	IFQ[f]
	MW rockfish	LE with trawl endorsement[a]	MW trawl	MW rockfish[c]	15–33	>70	IFQ[f]
	MW hake	LE with trawl endorsement[a]	MW trawl	P. hake[d]	17–40	>70	IFQ[f]
At-sea hake	MSCV	LE with MSCV endorsement[a]	MW trawl	P. hake[d]	8–138[e]	53–460[e]	IFQ[f]
	CP	LE with CP endorsement[a]	MW trawl	P. hake[d]	82–115	60–570	IFQ
	Tribal	n/a	MW trawl	P. hake[d]	<38	53–460	IFQ

[a] A.k.a. LE permit. All LE permits are issued by NOAA.
[b] Vessels with a California halibut permit, issued by the state of California, can land CA halibut under California's CA halibut fishery regulations.
[c] *Sebastes* spp.
[d] *Merluccius productus*.
[e] Average values for catcher vessels.
[f] Some vessels use EM in lieu of 100% observer coverage.

Table A-2. A description of permits, gears used, target groups, vessel length range, fishing depth range, and management of fisheries, sectors, and subsectors in federally managed, non-catch share, U.S. West Coast groundfish fisheries. For brevity, management descriptors are generalized for the given time period and are not meant to be complete or comprehensive. FG = fixed gear, IPHC = International Pacific Halibut Commission, P. = Pacific, OA = open access, LE = limited entry.

Sector	Subsector	Permit	Gear	Target	Vessel length (m)	Depth (m)	Management
Non-nearshore FG	Sablefish endorsed	LE permit with FG endorsement and sablefish quota[b]	Longline, pot	Sablefish[d]	7–32	20–1,300	Sablefish tier quotas[h]
	Sablefish nonendorsed[a]	LE permit with FG endorsement, no sablefish quota[b]	Longline, pot	Sablefish Rockfish[e] Flatfish[f]	7–32	20–1,300	Trip limits
	OA	n/a	Longline, pot	Sablefish, other groundfish	3–30	20–1,300	Trip limits
IPHC P. halibut directed	—	IPHC P. halibut permit[c]	Longline	P. halibut[g]	3–30	40–400	Trip limits[i]

[a] A.k.a. Zero Tier.
[b] A.k.a. LE permit. All LE permits are issued by NOAA.
[c] Issued by IPHC.
[d] *Anoplopomia fimbria*.
[e] *Sebastes* spp.
[f] Pleuronectiformes.
[g] *Hippoglossus stenolepis*.
[h] Seven-month season.
[i] Ten-hour fishing periods south of Point Chehalis, Washington. Legal size = <82 cm.

Table A-3. A description of permits, gears used, target groups, vessel length range, fishing depth range, and management of fisheries, sectors, and subsectors in state-managed U.S. West Coast fisheries. For brevity, management descriptors are generalized for the given time period and are not meant to be complete or comprehensive.

Sector	Permit	Gear	Target	Vessel length (m)	Depth (m)	Management
OA CA halibut	CA halibut permit[b]	Bottom trawl	CA halibut[d]	9–22	10–200	Fish mainly within the CA halibut trawl grounds. Minimum mesh size. 7-mo season.
Nearshore[a] fixed gear	OR or CA state nearshore permit/ endorsement	Variety of fixed gear[c]	Rockfish[e] Cabezon[f] Greenlings[g]	3–15	<100	Federal and state regulations. Area closures. Minimum mesh size. 2-mo trip limits.
Pink shrimp	WA, OR, or CA state pink shrimp permit	Shrimp trawl	Pink shrimp[h]	11–33	60–800	State regulations. Bycatch reduction devices. Trip limits on groundfish landings.
CA ridgeback prawn	Prawn permit[b]	Shrimp or bottom trawl	Golden, spot, ridgeback, or other prawn[i]	9–19	45–700	Oct–May season. Trip limits. Area restrictions. Landing requirements.
CA sea cucumber	Sea cucumber trawl permit[b]	Bottom trawl	CA sea cucumber[j]	9–12	<100	Logbook requirement. Area and seasonal closures.

[a] The state of Washington does not conduct a nearshore fishery.
[b] Issued by the state of California.
[c] Hand lines, pot gear, stick gear, rod-and-reel.
[d] *Paralichthys californicus*.
[e] *Sebastes* spp.
[f] *Scorpaenichthys marmoratus*.
[g] Hexagrammidae.
[h] *Pandalus jordani*.
[i] Includes *Crangon* spp., *Lysmata californica*, *Pandalus clanae*, *P. jordani*, *P. platyceros*, and *Sicyonia ingentis*.
[j] *Parastichopus californicus*.

Appendix B: Observed Mortalities—Random and Opportunistic

Table B-1. Observed random and opportunistic seabird mortalities, by year, fishery, gear type, and species, 2002–18. Randomly sampled mortalities are used in estimating total mortality across observed and unobserved vessels within each fleet. Opportunistically sampled mortalities occurred outside the fisheries observer's random samples and are simply added to the total mortality. The proportions of random to opportunistic samples are presented in Figure B-1.

				Observed number of samples	
Year	**Sector**	**Gear**	**Species**	**Random**	**Opportunistic**
2011	Catch share	Hook-and-line	Black-footed albatross	5.00	—
2011	Catch share	Hook-and-line	Gull, unidentified	1.00	—
2011	Catch share	Hook-and-line	Mew gull	1.00	—
2011	Catch share	Hook-and-line	Western gull	3.00	—
2012	Catch share	Hook-and-line	Black-footed albatross	4.94	—
2012	Catch share	Hook-and-line	Gull, unidentified	2.00	—
2012	Catch share	Hook-and-line	Western gull	41.55	—
2014	Catch share	Hook-and-line	Black-footed albatross	2.00	—
2014	Catch share	Hook-and-line	Northern fulmar	2.00	—
2017	Catch share	Hook-and-line	Black-footed albatross	1.00	—
2018	Catch share	Hook-and-line	Black-footed albatross	1.24	—
2003	LE fixed gear DTL	Hook-and-line	Cormorant, unidentified	1.00	—
2003	LE fixed gear DTL	Hook-and-line	Western gull	1.00	—
2005	LE fixed gear DTL	Hook-and-line	Brown pelican	1.00	—
2006	LE fixed gear DTL	Hook-and-line	Shearwater, unidentified	19.00	—
2008	LE fixed gear DTL	Hook-and-line	Gull, unidentified	3.00	—
2008	LE fixed gear DTL	Hook-and-line	Shearwater, unidentified	1.00	—
2009	LE fixed gear DTL	Hook-and-line	Western gull	1.00	—
2011	LE fixed gear DTL	Hook-and-line	Black-footed albatross	9.00	—
2011	LE fixed gear DTL	Hook-and-line	Black-footed albatross	4.00	—
2012	LE fixed gear DTL	Hook-and-line	Brown pelican	2.00	—
2012	LE fixed gear DTL	Hook-and-line	Double-crested cormorant	1.00	—
2012	LE fixed gear DTL	Hook-and-line	Gull, unidentified	1.00	—
2013	LE fixed gear DTL	Hook-and-line	Sooty shearwater	3.00	—
2015	LE fixed gear DTL	Hook-and-line	Black-footed albatross	3.40	—
2015	LE fixed gear DTL	Hook-and-line	Pink-footed shearwater	1.00	—
2002	LE sablefish	Hook-and-line	Black-footed albatross	1.00	—
2002	LE sablefish	Hook-and-line	Cormorant, unidentified	1.00	—
2002	LE sablefish	Hook-and-line	Western gull	4.00	—
2003	LE sablefish	Hook-and-line	Bird, unidentified	1.00	—
2003	LE sablefish	Hook-and-line	Black-footed albatross	8.00	—
2004	LE sablefish	Hook-and-line	Black-footed albatross	4.50	—
2005	LE sablefish	Hook-and-line	Black-footed albatross	—	1
2005	LE sablefish	Hook-and-line	Black-footed albatross	23.50	—
2005	LE sablefish	Hook-and-line	Gull, unidentified	—	1
2006	LE sablefish	Hook-and-line	Black-footed albatross	—	1
2006	LE sablefish	Hook-and-line	Black-footed albatross	13.58	—
2006	LE sablefish	Hook-and-line	Gull, unidentified	2.00	—
2007	LE sablefish	Hook-and-line	Black-footed albatross	48.40	—
2007	LE sablefish	Hook-and-line	Northern fulmar	2.00	—
2008	LE sablefish	Hook-and-line	Black-footed albatross	—	3

Table B-1 (continued). Observed random and opportunistic seabird mortalities, by year, fishery, gear type, and species, 2002–18.

				Observed number of samples	
Year	Sector	Gear	Species	Random	Opportunistic
2008	LE sablefish	Hook-and-line	Black-footed albatross	25.90	—
2008	LE sablefish	Hook-and-line	Northern fulmar	—	1
2010	LE sablefish	Hook-and-line	Black-footed albatross	33.19	—
2010	LE sablefish	Hook-and-line	Glaucous-winged gull	1.94	—
2011	LE sablefish	Hook-and-line	Alcid, unidentified	2.00	—
2011	LE sablefish	Hook-and-line	Bird, unidentified	1.67	—
2011	LE sablefish	Hook-and-line	Black-footed albatross	21.44	—
2011	LE sablefish	Hook-and-line	Black-footed albatross	2.00	—
2011	LE sablefish	Hook-and-line	Short-tailed albatross	1.00	—
2011	LE sablefish	Hook-and-line	Sooty shearwater	1.00	—
2011	LE sablefish	Hook-and-line	Western gull	3.00	—
2012	LE sablefish	Hook-and-line	Arctic herring gull	7.60	—
2012	LE sablefish	Hook-and-line	Black-footed albatross	36.02	—
2012	LE sablefish	Hook-and-line	California gull	1.00	—
2012	LE sablefish	Hook-and-line	Glaucous-winged gull	2.00	—
2012	LE sablefish	Hook-and-line	Gull, unidentified	5.00	—
2012	LE sablefish	Hook-and-line	Laysan albatross	1.88	—
2012	LE sablefish	Hook-and-line	Northern fulmar	—	1
2012	LE sablefish	Hook-and-line	Northern fulmar	6.99	—
2012	LE sablefish	Hook-and-line	Pink-footed shearwater	3.13	—
2012	LE sablefish	Hook-and-line	Ring-billed gull	1.00	—
2012	LE sablefish	Hook-and-line	Western gull	9.53	—
2013	LE sablefish	Hook-and-line	Black-footed albatross	13.00	—
2013	LE sablefish	Hook-and-line	Sooty shearwater	2.00	—
2013	LE sablefish	Hook-and-line	Western gull	1.00	—
2014	LE sablefish	Hook-and-line	Bird, unidentified	1.00	—
2014	LE sablefish	Hook-and-line	Black-footed albatross	2.00	—
2014	LE sablefish	Hook-and-line	Gull, unidentified	1.00	—
2014	LE sablefish	Hook-and-line	Western gull	1.00	—
2015	LE sablefish	Hook-and-line	Bird, unidentified	1.00	—
2015	LE sablefish	Hook-and-line	Black-footed albatross	20.34	—
2015	LE sablefish	Hook-and-line	Gull, unidentified	2.00	—
2015	LE sablefish	Hook-and-line	Northern fulmar	1.00	—
2015	LE sablefish	Hook-and-line	Shearwater, unidentified	6.00	—
2015	LE sablefish	Hook-and-line	Shearwater, unidentified	7.00	—
2015	LE sablefish	Hook-and-line	Western gull	2.00	—
2015	LE sablefish	Hook-and-line	Western gull	1.00	—
2016	LE sablefish	Hook-and-line	Black-footed albatross	9.00	—
2016	LE sablefish	Hook-and-line	Red-necked phalarope	—	1
2017	LE sablefish	Hook-and-line	Black-footed albatross	22.38	—
2017	LE sablefish	Hook-and-line	Gull, unidentified	1.00	—
2017	LE sablefish	Hook-and-line	Northern fulmar	3.00	—
2018	LE sablefish	Hook-and-line	Black-footed albatross	14.00	—
2018	LE sablefish	Hook-and-line	Sooty shearwater	18.00	—
2006	Nearshore	Hook-and-line	Brown pelican	1.00	—
2008	Nearshore	Hook-and-line	Western gull	1.00	—
2009	Nearshore	Hook-and-line	Bird, unidentified	1.00	—
2010	Nearshore	Hook-and-line	Brown pelican	1.00	—
2011	Nearshore	Hook-and-line	Common loon	1.00	—

Table B-1 (continued). Observed random and opportunistic seabird mortalities, by year, fishery, gear type, and species, 2002–18.

Year	Sector	Gear	Species	Observed number of samples	
				Random	Opportunistic
2011	Nearshore	Hook-and-line	Common murre	1.00	—
2011	Nearshore	Hook-and-line	Western gull	1.00	—
2013	Nearshore	Hook-and-line	Brown pelican	1.00	—
2013	Nearshore	Hook-and-line	Common murre	1.00	—
2015	Nearshore	Hook-and-line	Brandt's cormorant	1.00	—
2015	Nearshore	Hook-and-line	Common murre	1.00	—
2017	Nearshore	Hook-and-line	Gull, unidentified	1.00	—
2017	Nearshore	Hook-and-line	Western gull	1.00	—
2010	Non-EM EFP	Hook-and-line	Black-footed albatross	1.00	—
2007	OA fixed gear	Hook-and-line	Black-footed albatross	1.00	—
2010	OA fixed gear	Hook-and-line	Black-footed albatross	1.86	—
2014	OA fixed gear	Hook-and-line	Gull, unidentified	1.00	—
2017	OA fixed gear	Hook-and-line	Black-footed albatross	1.00	—
2017	Pacific halibut derby	Hook-and-line	Black-footed albatross	7.00	—
2017	Pacific halibut derby	Hook-and-line	Shearwater, unidentified	1.00	—
2011	Catch share	Bottom trawl	Arctic herring gull	1.00	—
2011	Catch share	Bottom trawl	Northern fulmar	1.00	—
2012	Catch share	Bottom trawl	Common murre	1.00	—
2012	Catch share	Bottom trawl	Northern fulmar	1.00	—
2013	Catch share	Bottom trawl	Laysan albatross	—	1
2013	Catch share	Bottom trawl	Sooty shearwater	2.00	—
2013	Catch share	Bottom trawl	Storm-petrel, unidentified	1.00	—
2014	Catch share	Bottom trawl	California gull	1.00	—
2015	Catch share	Bottom trawl	Black-footed albatross	1.00	—
2015	Catch share	Bottom trawl	Black-footed albatross	1.00	—
2016	Catch share	Bottom trawl	Black-footed albatross	—	1
2016	Catch share	Bottom trawl	Leach's storm-petrel	—	3
2017	Catch share	Bottom trawl	Leach's storm-petrel	1.00	—
2010	LE and OA CA halibut	Bottom trawl	Cormorant, unidentified	1.00	—
2003	LE CA halibut	Bottom trawl	Brandt's cormorant	1.00	—
2003	LE CA halibut	Bottom trawl	Common murre	36.00	—
2003	LE CA halibut	Bottom trawl	Cormorant, unidentified	2.00	—
2004	LE CA halibut	Bottom trawl	Common murre	5.00	—
2004	LE CA halibut	Bottom trawl	Cormorant, unidentified	2.00	—
2002	LE trawl	Bottom trawl	Leach's storm-petrel	6.51	—
2002	LE trawl	Bottom trawl	Northern fulmar	1.00	—
2004	LE trawl	Bottom trawl	Black-footed albatross	—	1
2004	LE trawl	Bottom trawl	Cassin's auklet	—	1
2004	LE trawl	Bottom trawl	Common murre	1.00	—
2004	LE trawl	Bottom trawl	Storm-petrel, unidentified	1.00	—
2005	LE trawl	Bottom trawl	Green-winged teal	—	10
2005	LE trawl	Bottom trawl	Gull, unidentified	—	1
2005	LE trawl	Bottom trawl	White-winged scoter	—	3
2007	LE trawl	Bottom trawl	Leach's storm-petrel	—	1
2009	LE trawl	Bottom trawl	Northern fulmar	—	1
2010	LE trawl	Bottom trawl	Cassin's auklet	—	1

Table B-1 (continued). Observed random and opportunistic seabird mortalities, by year, fishery, gear type, and species, 2002–18.

Year	Sector	Gear	Species	Observed number of samples	
				Random	Opportunistic
2003	OA CA halibut	Bottom trawl	Common murre	1.00	—
2005	OA CA halibut	Bottom trawl	Cormorant, unidentified	1.00	—
2007	OA CA halibut	Bottom trawl	Cormorant, unidentified	1.00	—
2011	OA CA halibut	Bottom trawl	Common murre	1.00	—
2014	OA CA halibut	Bottom trawl	Brandt's cormorant	1.00	—
2015	OA CA halibut	Bottom trawl	Bird, unidentified	1.00	—
2015	OA CA halibut	Bottom trawl	Brandt's cormorant	1.00	—
2015	OA CA halibut	Bottom trawl	Common murre	3.00	—
2016	OA CA halibut	Bottom trawl	Common murre	2.00	—
2016	OA CA halibut	Bottom trawl	Cormorant, unidentified	1.00	—
2016	OA CA halibut	Bottom trawl	Western gull	1.00	—
2017	OA CA halibut	Bottom trawl	Brandt's cormorant	1.00	—
2017	OA CA halibut	Bottom trawl	Common murre	5.00	—
2017	OA CA halibut	Bottom trawl	Cormorant, unidentified	1.00	—
2018	OA CA halibut	Bottom trawl	Brandt's cormorant	15.00	—
2018	OA CA halibut	Bottom trawl	Common murre	2.00	—
2016	Unknown fishery	Bottom trawl	Black-footed albatross	—	1
2003	Catcher–processor	Midwater trawl	Black-footed albatross	3.00	—
2004	Catcher–processor	Midwater trawl	Alcid, unidentified	3.00	—
2004	Catcher–processor	Midwater trawl	Black-footed albatross	—	1
2004	Catcher–processor	Midwater trawl	Common murre	3.00	—
2004	Catcher–processor	Midwater trawl	Northern fulmar	21.00	—
2004	Catcher–processor	Midwater trawl	Shearwater, unidentified	8.00	—
2005	Catcher–processor	Midwater trawl	Black-footed albatross	2.00	—
2005	Catcher–processor	Midwater trawl	Sooty shearwater	2.00	—
2006	Catcher–processor	Midwater trawl	Black-footed albatross	—	1
2006	Catcher–processor	Midwater trawl	Black-footed albatross	2.00	—
2007	Catcher–processor	Midwater trawl	Black-footed albatross	—	2
2007	Catcher–processor	Midwater trawl	Gull, unidentified	—	15
2007	Catcher–processor	Midwater trawl	Northern fulmar	—	11
2007	Catcher–processor	Midwater trawl	Northern fulmar	51.00	—
2007	Catcher–processor	Midwater trawl	Shearwater, unidentified	—	1
2008	Catcher–processor	Midwater trawl	Bird, unidentified	2.00	—
2008	Catcher–processor	Midwater trawl	Black-footed albatross	1.00	—
2008	Catcher–processor	Midwater trawl	Northern fulmar	—	2
2008	Catcher–processor	Midwater trawl	Northern fulmar	2.00	—
2008	Catcher–processor	Midwater trawl	Tubenoses, unidentified	2.00	—
2009	Catcher–processor	Midwater trawl	Black-footed albatross	—	1
2009	Catcher–processor	Midwater trawl	Cassin's auklet	2.00	—
2009	Catcher–processor	Midwater trawl	Northern fulmar	32.00	—
2010	Catcher–processor	Midwater trawl	Black-footed albatross	—	2
2010	Catcher–processor	Midwater trawl	Black-footed albatross	1.00	—
2010	Catcher–processor	Midwater trawl	Common murre	2.00	—
2010	Catcher–processor	Midwater trawl	Northern fulmar	17.00	—
2011	Catcher–processor	Midwater trawl	Black-footed albatross	—	5
2011	Catcher–processor	Midwater trawl	Gull, unidentified	—	8
2011	Catcher–processor	Midwater trawl	Northern fulmar	—	3
2011	Catcher–processor	Midwater trawl	Northern fulmar	22.00	—

Table B-1 (continued). Observed random and opportunistic seabird mortalities, by year, fishery, gear type, and species, 2002–18.

				Observed number of samples	
Year	Sector	Gear	Species	Random	Opportunistic
2011	Catcher–processor	Midwater trawl	Tubenoses, unidentified	—	4
2012	Catcher–processor	Midwater trawl	Black-footed albatross	—	1
2012	Catcher–processor	Midwater trawl	Northern fulmar	2.00	—
2013	Catcher–processor	Midwater trawl	Arctic herring gull	—	4
2013	Catcher–processor	Midwater trawl	Bird, unidentified	—	1
2013	Catcher–processor	Midwater trawl	Black-footed albatross	—	2
2013	Catcher–processor	Midwater trawl	Cassin's auklet	2.00	—
2013	Catcher–processor	Midwater trawl	Gull, unidentified	—	1
2013	Catcher–processor	Midwater trawl	Leach's storm-petrel	2.00	—
2013	Catcher–processor	Midwater trawl	Northern fulmar	—	48
2013	Catcher–processor	Midwater trawl	Northern fulmar	4.00	—
2013	Catcher–processor	Midwater trawl	Shearwater, unidentified	—	1
2013	Catcher–processor	Midwater trawl	Shearwater, unidentified	2.00	—
2013	Catcher–processor	Midwater trawl	Sooty shearwater	—	1
2014	Catcher–processor	Midwater trawl	Bird, unidentified	—	1
2014	Catcher–processor	Midwater trawl	Black-footed albatross	—	1
2014	Catcher–processor	Midwater trawl	Northern fulmar	2.00	—
2015	Catcher–processor	Midwater trawl	Black-footed albatross	—	1
2015	Catcher–processor	Midwater trawl	Gull, unidentified	—	2
2015	Catcher–processor	Midwater trawl	Gull, unidentified	2.00	—
2015	Catcher–processor	Midwater trawl	Leach's storm-petrel	2.00	—
2015	Catcher–processor	Midwater trawl	Northern fulmar	—	5
2015	Catcher–processor	Midwater trawl	Northern fulmar	7.00	—
2016	Catcher–processor	Midwater trawl	Black-footed albatross	—	2
2016	Catcher–processor	Midwater trawl	Gull, unidentified	—	2
2016	Catcher–processor	Midwater trawl	Gull, unidentified	2.00	—
2016	Catcher–processor	Midwater trawl	Leach's storm-petrel	2.00	—
2016	Catcher–processor	Midwater trawl	Northern fulmar	9.00	—
2016	Catcher–processor	Midwater trawl	Shearwater, unidentified	2.00	—
2017	Catcher–processor	Midwater trawl	Black-footed albatross	—	1
2017	Catcher–processor	Midwater trawl	Cassin's auklet	2.00	—
2017	Catcher–processor	Midwater trawl	Gull, unidentified	—	2
2017	Catcher–processor	Midwater trawl	Leach's storm-petrel	2.00	—
2017	Catcher–processor	Midwater trawl	Northern fulmar	—	1
2018	Catcher–processor	Midwater trawl	Black-footed albatross	—	2
2018	Catcher–processor	Midwater trawl	Northern fulmar	2.00	—
2018	Catcher–processor	Midwater trawl	Warbler, unidentified	4.00	—
2017	Midwater hake EM	Midwater trawl	Seabird, unidentified	1.00	—
2005	MS catcher vessels*	Midwater trawl	Bird, unidentified	2.00	—
2005	MS catcher vessels*	Midwater trawl	Common murre	2.00	—
2005	MS catcher vessels*	Midwater trawl	Northern fulmar	2.00	—
2008	MS catcher vessels*	Midwater trawl	Bird, unidentified	2.00	—
2012	MS catcher vessels*	Midwater trawl	Northern fulmar	2.00	—
2014	MS catcher vessels*	Midwater trawl	Cassin's auklet	2.00	—
2015	MS catcher vessels*	Midwater trawl	Common murre	2.00	—
2016	MS catcher vessels*	Midwater trawl	Cassin's auklet	—	1
2011	Tribal	Midwater trawl	Northern fulmar	2.00	—

* MS = mothership.

Table B-1 (continued). Observed random and opportunistic seabird mortalities, by year, fishery, gear type, and species, 2002–18.

				Observed number of samples	
Year	**Sector**	**Gear**	**Species**	**Random**	**Opportunistic**
2011	Pink shrimp	Shrimp trawl	Pink-footed shearwater	1.00	—
2012	Pink shrimp	Shrimp trawl	Sooty shearwater	14.00	—
2013	Pink shrimp	Shrimp trawl	Sooty shearwater	13.54	—
2014	Pink shrimp	Shrimp trawl	Gull, unidentified	1.00	—
2014	Pink shrimp	Shrimp trawl	Shearwater, unidentified	1.00	—
2014	Pink shrimp	Shrimp trawl	Shearwater, unidentified	1.00	—
2015	Pink shrimp	Shrimp trawl	Common murre	—	1
2015	Pink shrimp	Shrimp trawl	Leach's storm-petrel	—	9
2015	Pink shrimp	Shrimp trawl	Sooty shearwater	—	1
2018	Ridgeback prawn	Shrimp trawl	Brandt's cormorant	5.00	—
2011	Catch share	Pot	Northern fulmar	1.00	—
2013	Catch share	Pot	Storm-petrel, unidentified	1.00	—
2018	Catch share EM	Pot	Gull, unidentified	—	1
2014	LE sablefish	Pot	Black-footed albatross	—	1
2007	Nearshore	Pot	Cormorant, unidentified	1.00	—
2009	Nearshore	Pot	Cormorant, unidentified	1.00	—
2012	Nearshore	Pot	Cormorant, unidentified	1.00	—
2012	Nearshore	Pot	Double-crested cormorant	1.00	—
2014	Nearshore	Pot	Brandt's cormorant	3.00	—
2016	Nearshore	Pot	Cormorant, unidentified	1.07	—

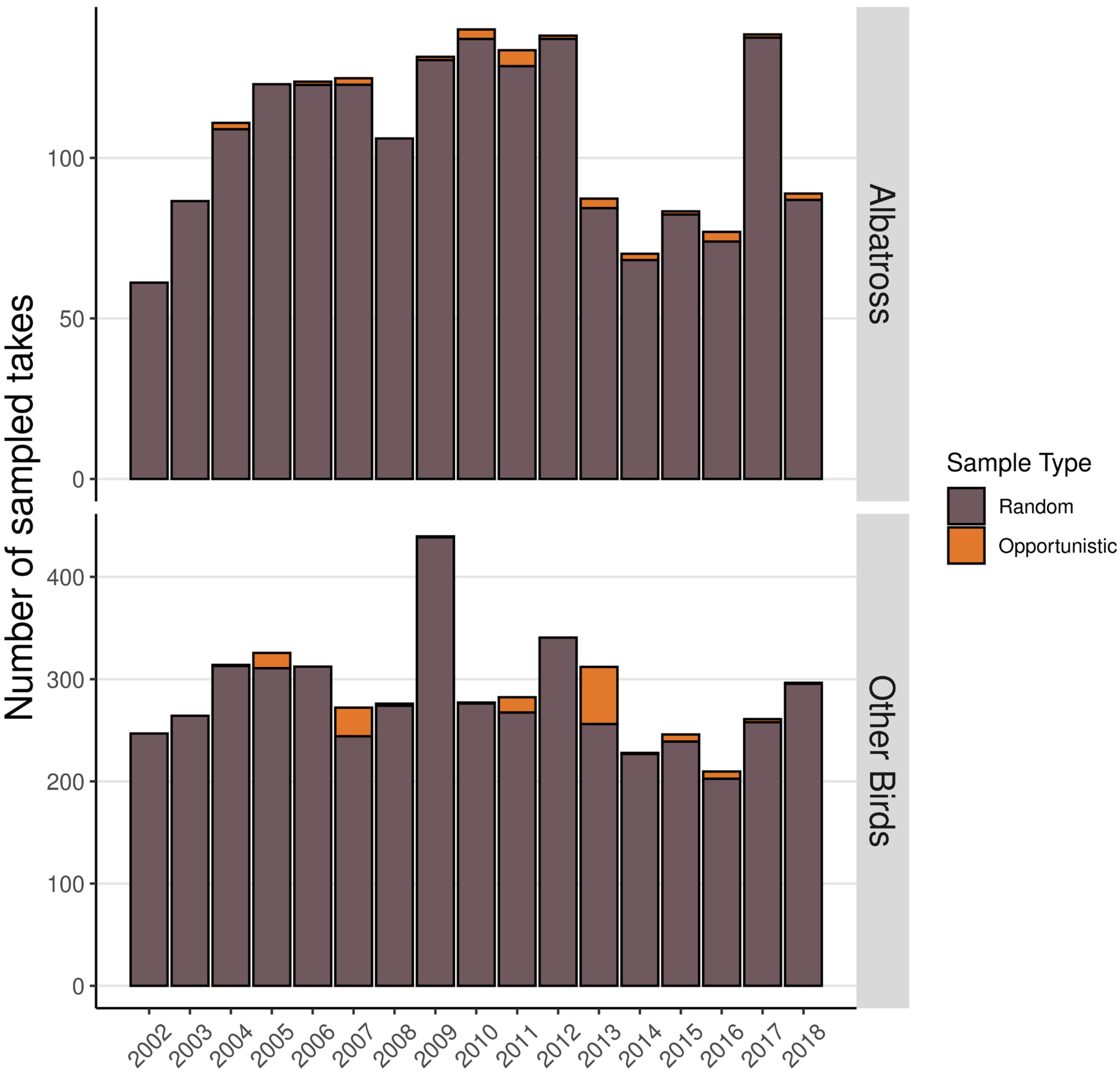

Figure B-1. Random (brown) and opportunistic (orange) samples as a fraction of total samples, by year.

List of Species

Common name	Species
Albatross, unidentified	Diomedeidae
Alcid, unidentified	Alcidae
American coot	*Fulica americana*
American white pelican	*Pelecanus erythrorhynchos*
Ancient murrelet	*Synthliboramphus antiquus*
Arctic herring gull	*Larus smithsonianus*
Bird, unidentified	Aves
Black storm-petrel	*Oceanodroma melania*
Black-footed albatross	*Phoebastria nigripes*
Black-legged kittiwake	*Rissa tridactyla*
Black-vented shearwater	*Puffinus opisthomelas*
Brandt’s cormorant	*Phalacrocorax penicillatus*
Brown booby	*Sula leucogaster*
Brown pelican	*Pelecanus occidentalis*
California gull	*Larus californicus*
California least tern	*Sternula antillarum browni*
Caspian tern	*Hydroprogne caspia*
Cassin’s auklet	*Ptychoramphus aleuticus*
Common loon	*Gavia immer*
Common murre	*Uria aalge*
Cormorant, unidentified	Phalacrocoracidae
Double-crested cormorant	*Phalacrocorax auritus*
Fork-tailed storm-petrel	*Hydrobates furcatus*
Glaucous-winged gull	*Larus glaucescens*
Grebe, unidentified	Podicipedidae
Green-winged teal	*Anas crecca carolinensis*
Guillemot, unidentified	Cepphus
Gull, unidentified	Laridae
Heermann’s gull	*Larus heermanni*
Herring gull	*Larus argentatus*
Horned grebe	*Podiceps auritus*
Laysan albatross	*Phoebastria immutabilis*
Leach’s storm-petrel	*Hydrobates leucorhous*

Common name	Species
Least storm-petrel	*Oceanodroma microsoma*
Lesser goldfinch	*Spinus psaltria*
Loon, unidentified	Gaviidae
Marbled murrelet	*Brachyramphus marmoratus*
Mew gull	*Larus canus*
Murre, unidentified	Uria
Northern fulmar	*Fulmarus glacialis*
Orange-crowned warbler	*Leiothlypis celata*
Pacific loon	*Gavia pacifica*
Parasitic jaeger	*Stercorarius parasiticus*
Pelagic cormorant	*Phalacrocorax pelagicus*
Pigeon guillemot	*Cepphus columba*
Pink-footed shearwater	*Ardenna creatopus*
Pomarine jaeger	*Stercorarius pomarinus*
Red-necked grebe	*Podiceps grisegena*
Red-necked phalarope	*Phalaropus lobatus*
Red-throated loon	*Gavia stellata*
Rhinoceros auklet	*Cerorhinca monocerata*
Ring-billed gull	*Larus delawarensis*
Semipalmated plover	*Charadrius semipalmatus*
Shearwater, unidentified	Puffinus
Short-tailed albatross	*Phoebastria albatrus*
Short-tailed jaeger	*Stercorarius longicaudus*
Short-tailed shearwater	*Ardenna tenuirostris*
Snowy plover	*Charadrius nivosus*
Sooty shearwater	*Ardenna grisea*
South polar skua	*Stercorarius maccormicki*
Storm-petrel, unidentified	Hydrobatidae
Tufted puffin	*Fratercula cirrhata*
Western grebe	*Aechmophorus occidentalis*
Western gull	*Larus occidentalis*
White-winged scoter	*Melanitta deglandi*
Wilson’s warbler	*Cardellina pusilla*

Recently published by the Northwest Fisheries Science Center

NOAA Technical Memorandum NMFS-NWFSC-

164 **Crozier, L. G., L. E. Wiesebron, B. J. Burke, D. Widener, and T. Marsh. 2021.** Reframing Steelhead Migration Behavior: A Population Perspective on Migration Rate and Survival Through the Columbia and Snake Rivers. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-164. https://doi.org/10.25923/dds5-jg64

163 **Jannot, J. E., K. E. Richerson, K. A. Somers, V. J. Tuttle, R. S. Shama, and J. T. McVeigh. 2021.** Pacific Halibut Bycatch in U.S. West Coast Groundfish Fisheries, 2002–19. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-163. https://doi.org/10.25923/8y03-z703

162 **Sol, S. Y., B. Anulacion, D. P. Lomax, P. Chittaro, P. Moran, G. M. Ylitalo, A. Hanson, C. Corbett, and L. L. Johnson. 2021.** Juvenile Salmon Ecology in Tidal Freshwater Wetlands in the Lower Columbia River Estuary. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-162. https://doi.org/10.25923/2bfz-ah24

161 **Clarke, M. E., E. L. Fruh, A. Powell, J. Anderson, J. C. Taylor, and C. E. Whitmire. 2020.** Autonomous Underwater Vehicle (AUV) Survey at The Footprint and Piggy Bank in the Southern California Bight, 2011. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-161. https://doi.org/10.25923/mfq8-6773

160 **Harvey, C., N. Garfield, G. Williams, N. Tolimieri, K. Andrews, K. Barnas, E. Bjorkstedt, S. Bograd, J. Borchert, C. Braby, R. Brodeur, B. Burke, J. Cope, A. Coyne, D. Demer, L. deWitt, J. Field, J. Fisher, P. Frey, T. Good, C. Grant, C. Greene, E. Hazen, D. Holland, M. Hunter, K. Jacobson, M. Jacox, J. Jahncke, C. Juhasz, I. Kaplan, S. Kasperski, S. Kim, D. Lawson, A. Leising, A. Manderson, N. Mantua, S. Melin, R. Miller, S. Moore, C. Morgan, B. Muhling, S. Munsch, K. Norman, J. Parrish, A. Phillips, R. Robertson, D. Rudnick, K. Sakuma, J. Samhouri, J. Santora, I. Schroeder, S. Siedlecki, K. Somers, B. Stanton, K. Stierhoff, W. Sydeman, A. Thompson, D. Trong, P. Warzybok, B. Wells, C. Whitmire, M. Williams, T. Williams, J. Zamon, S. Zeman, V. Zubkousky-White, and J. Zwolinski. 2020.** Ecosystem Status Report of the California Current for 2019–20: A Summary of Ecosystem Indicators Compiled by the California Current Integrated Ecosystem Assessment Team (CCIEA). U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-160. https://doi.org/10.25923/e5rb-9f55

159 **Hartley, M. L., D. M. Schug, K. F. Wellman, B. Lane, W. T. Fairgrieve, and J. A. Luckenbach. 2020.** Sablefish Aquaculture: An Assessment of Recent Developments and Their Potential for Enhancing Profitability. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-159. https://doi.org/10.25923/cb0y-n468

158 **Richerson, K. E., J. E. Jannot, Y.-W. Lee, J. T. McVeigh, K. A. Somers, V. J. Tuttle, and S. Wang. 2020.** Observed and Estimated Bycatch of Green Sturgeon in 2002–17 U.S. West Coast Groundfish Fisheries. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-158. https://doi.org/10.25923/sn5z-w384

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